U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY—BULLETIN No. 45.
L. O. HOWARD, ENTOMOLOGIST.

THE MEXICAN COTTON BOLL WEEVIL.

PREPARED UNDER THE DIRECTION OF THE ENTOMOLOGIST

BY

W. D. HUNTER and W. E. HINDS.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1904.

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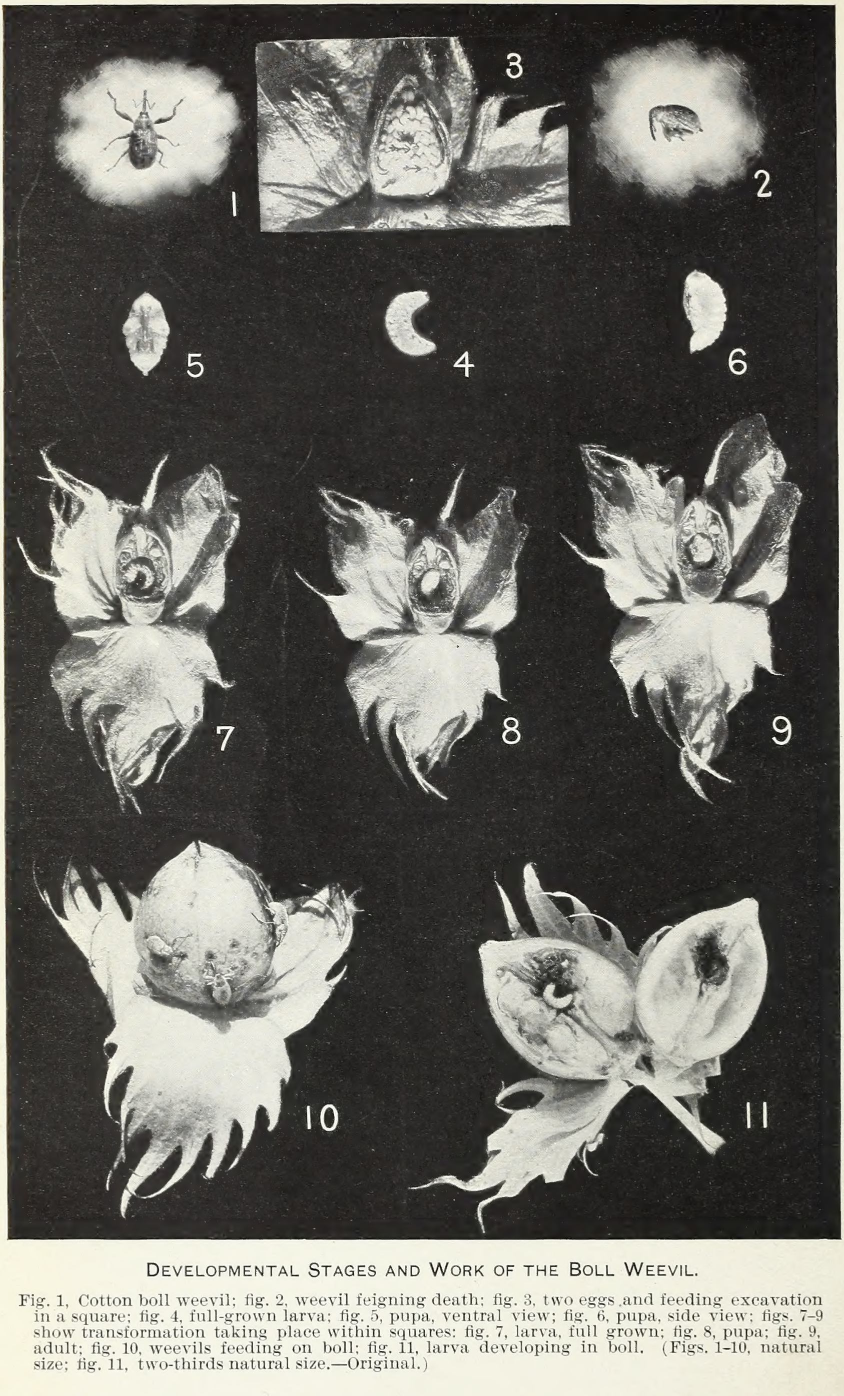

DEVELOPMENTAL STAGES AND WORK OF THE BOLL WEEVIL.

Fig. 1, Cotton boll weevil; fig. 2, weevil feigning death; fig. 3, two eggs and feeding excavation in a square; fig. 4, full-grown larva; fig. 5, pupa, ventral view; fig. 6, pupa, side view; figs. 7–9 show transformation taking place within squares: fig. 7, larva, full grown; fig. 8, pupa; fig. 9, adult; fig. 10, weevils feeding on boll; fig. 11, larva developing in boll. (Figs. 1–10, natural size; fig. 11, two-thirds natural size.—Original.)

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF ENTOMOLOGY,
Washington, D. C., February 20, 1904.

SIR: I have the honor to transmit herewith for publication an account of the Mexican cotton boll weevil, prepared under my direction by Messrs. W. D. Hunter and W. E. Hinds, special field agents of this Division. Mr. Hunter has been engaged for three years in investigations of this very important injurious insect, his work extending all through the infested portions of Texas and to some extent into Mexico. Mr. Hinds for two years has been devoting his whole time to this subject, having been stationed for the most part at Victoria, Tex., in charge of laboratory work. The bulletin as a whole is a remarkably careful and complete treatment of the entomological aspects of the investigation. It seems to me as complete a treatise of the life history of a single species as has ever been published. The necessity for the most perfect knowledge of every detail of the habits of this great enemy to the cotton crop must be obvious, since only upon such perfect knowledge can we authoritatively base remedial work and can we authoritatively indicate the uselessness of many of the remedies proposed by ingenious and inventive persons. The sixteen half-tone and other plates and six text figures are an essential part of the report.

I recommend the publication of this paper as Bulletin No. 45 of this Division.

Respectfully,

L. O. HOWARD,
Entomologist.

Hon. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

The Mexican cotton boll weevil (*Anthonomus grandis* Boh.) has the unique record of developing in less than twenty years from a most obscure species to undoubtedly one of the most important economically in the world. It was first brought to the attention of the Division of Entomology as an enemy of cotton in Texas in 1894. Before it had invaded more than half a dozen counties in the extreme southern portion of Texas several entomologists were sent to the region in connection with this work. Enough was soon discovered to indicate the most feasible plans for avoiding damage by the pest. These original plans, based upon investigations of the life history of the insect, with modifications, for the most part due to climatic conditions in regions quite dissimilar to the lower portion of Texas, are still the basis for all that is known in combating the pest. However, at that time it was necessary to pay particular attention to the immediate economic phases of the problem, and a detailed study of the habits of the insect was impossible. In 1902, by the aid of a special appropriation by Congress, it became possible to establish a complete field laboratory in the portion of Texas in which the weevil had been known to exist at that time for about eight years, where a careful investigation could be conducted regarding the points in the life history of the pest that offered even remote chances of suggesting means of avoiding damage. The results of the work at this laboratory that have been of more immediate economic bearing have already been published in farmers' bulletins of this Department. However, as will be seen from the following pages, a very large mass of information concerning all the habits of the boll weevil has been accumulated. Not only on account of the great economic importance of the problem and the demand for information from numerous quarters concerning the biology of the pest, but also on account of the fact that the methods followed in this work have been to some extent original, and may be of use in connection with the investigation of other insects, it is thought advisable to publish a great number of the observations that have been made.

The historical and economic features, to which reference has been made elsewhere in the publications of the Division, are included to bring together in convenient form practically all that is known regard-

ing the species. Much information obtained by the earlier investigators of the Division of Entomology, Dr. L. O. Howard, Mr. C. L. Marlatt, Mr. C. H. T. Townsend, and Mr. E. A. Schwarz, has been used. On account of the painstaking character of the work of Mr. Schwarz, and his intimate knowledge of related species, his reports, largely unpublished, have been found especially valuable. In presenting this work the authors have taken care to state fully the data furnishing the basis for the various conclusions. Under each important heading will be found, first, a description of the methods and apparatus employed; second, a full and in many cases tabular statement of observations; third, the obvious conclusions. Care has constantly been exercised to avoid errors likely to result from artificial conditions in the laboratory. A large part of the work of the past year was in ascertaining how closely laboratory results corresponded to the actual conditions in the field. The writers have on many occasions been surprised to discover how close the correspondence is, and consider that the demonstration on a large scale of the possibility of accurately determining the details of the life history and habits of an insect by laboratory investigations is by no means the least important of the results of the investigation.

The laboratory work which has led to this paper was planned originally by the senior author, who has also supervised the later developments of it. However, practically all the labor of conducting the experiments and observations has devolved upon the junior author, who has suggested from time to time many important modifications of the original plan. Specifically, all of the bulletin except the first portion, dealing with historical matters, the destructiveness of the pest, and the prospects, and the last portion, dealing with methods of combating it, was written by the junior author, although revised in some particulars after it had been submitted by him. The illustrations used are from photographs taken for this work by the junior author, with the exception of the text figures and the illustrations of insects often mistaken for the boll weevil, of which those marked "original" are, with one exception, from drawings prepared by Miss L. L. Howenstein, one of the artists of the Division of Entomology.

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HISTORICAL.

There is very little certainty regarding the history of the Mexican cotton boll weevil before it came to the attention of the Division of Entomology in Texas in 1894. The species was described by Boheman in 1843 from specimens received from Vera Cruz, and it was recorded by Suffrian in 1871 as occurring at Cardenas and San Cristobal in Cuba. Written documents in the archives at Monclova, in the State of Coahuila, Mexico, indicate that the cultivation of cotton was practically abandoned in the vicinity of that town about the year 1848, or at least that some insect caused very great fears that it would be necessary to abandon the cultivation of cotton. A rather careful investigation of the records makes it by no means clear that the insect was the boll weevil, although there is a rather firmly embedded popular notion in Mexico, as well as in the Southern United States, that the damage must have been perpetrated by that species. As far as the accounts indicate, it might have been the bollworm (*Heliothis armiger*) or the cotton caterpillar (*Aletia argillacea*).

From the time of the note by Suffrian regarding the occurrence of the weevil in Cuba in 1871 up to 1885 there has been found no published record concerning it. In 1885, however, C. V. Riley, then Entomologist of the Department of Agriculture, published in the report of the Commissioner a very brief note to the effect that *Anthonomus grandis* had been reared in the Department from dwarfed cotton bolls sent by Dr. Edward Palmer from northern Mexico. This is the first account associating the species with damage to cotton. The material referred to was collected in the State of Coahuila, supposedly not far from the town of Monclova. The exact date at which the insect crossed the Rio Grande into Texas is as uncertain as the means whereby this was accomplished. All that can be found, which is mostly in the form of testimony of planters in the vicinity of Brownsville, indicates that the pest first made its appearance in that locality about 1892. In 1894 it had spread to half a dozen counties in the Brownsville region, and during the last months of the year was brought to the attention of the Division of Entomology as an important enemy of cotton. Mr. C. H. T. Townsend was immediately sent

to the territory affected. His report was published in March, 1895. It dealt with the life history and habits of the insect, which were then completely unknown, the probable method of its importation, the damage that might result from its work, and closed with recommendations for fighting it and preventing its further advance in the cotton-producing regions of Texas. It is much to be regretted that the State of Texas did not adopt at that time the suggestion made by the Division of Entomology that a belt be established along the Rio Grande in which the cultivation of cotton should be prohibited, and thus cut off the advance of the insect.

The events of the last few years have verified the prediction of the Division of Entomology in regard to the advance made and the damage caused by the insect.

In 1895 the insect was found by the entomologists, who continued the investigation started the year before, as far north as San Antonio and as far east as Wharton. Such a serious advance toward the principal cotton-producing region of the State caused the Division to continue its investigations during practically the whole season. The results of this work were incorporated in a circular by Doctor Howard, published early in 1896, in both Spanish and English editions.

An unusual drought in the summer of 1896 prevented the maturity of the fall broods of the weevil, and consequently there was no extension of the territory affected. It should be stated in this connection that the region from San Antonio to Corpus Christi and thence to Brownsville will frequently pass through similar experiences, which will be quite different from anything that may be expected to occur in regions where the rainfall is more certain. In 1900 as well as in 1903, in all or part of the region referred to, the numbers of the weevil were reduced by climatic conditions, principally a scanty rainfall, so that they were comparatively unimportant factors. During 1896 the investigations were continued and the results published in another circular issued in February, 1897. This circular was published in Spanish and German, as well as English editions, for the benefit of the very large foreign population in southern Texas.

The season of 1897 was in many respects almost as unfavorable as that of 1896, although the pest increased its range to the region about Yoakum and Gonzales. Although this extension was small it was exceedingly important, because the richest cotton lands in the United States were beginning to be invaded. The problem had thus become so important that Mr. Townsend was stationed in Mexico, in a region supposed to be the original home of the insect, for several months to discover, if possible, any parasites or diseases that might be affecting it, with the object of introducing them to prey upon the pest in Texas. Unfortunately nothing was found that gave any hope of material assistance in the warfare against the weevil.

The season of 1898 was very favorable for the insect. Bastrop,

Lee, and Burleson counties became invaded, and some isolated colonies were found across the Brazos River, in Waller and Brazos counties. Investigations by the Division of Entomology were continued, and a summary of the work, dealing especially with experiments conducted by Mr. C. L. Marlatt in the spring of 1896, was published in still another circular. At this time the legislature of the State of Texas made provision for the appointment of a State entomologist and provided a limited appropriation for an investigation of means of combating the boll weevil. In view of this fact the Division of Entomology discontinued, temporarily, the work that had been carried on by having agents in the field almost constantly for four years, and all correspondence was referred to the State entomologist; but, unfortunately, the insect continued to spread, and it soon became apparent that other States than Texas were threatened. This caused the work to be taken up anew by the Division of Entomology in 1901, in accordance with a special appropriation by Congress for an investigation independent of that being carried on by the State of Texas and with special reference to the discovery, if possible, of means of preventing the insect from spreading into adjoining States.

In accordance with this provision an agent was sent to Texas in March and remained in that State until December. He carried on cooperative work upon eight of the larger plantations in the weevil region. The result of his observations was to suggest the advisability of a considerable enlargement of the scope of the work. It had been found that simple cooperative work with the planters was exceedingly unsatisfactory. The need of a means of testing the recommendations of the Division of Entomology upon a large scale, and thereby furnishing actual demonstrations to the planters, became apparent. Consequently, at the suggestion of the Department of Agriculture, provision for an enlargement of the work was made by Congress. Agreements were entered into with two large planters in typical situations for testing the principal features of the cultural system of controlling the pest upon a large scale. In this way 125 acres at Victoria and 200 acres at Calvert were employed. At the same time the headquarters and laboratory of the special investigation were established at Victoria, and such matters as parasites, the possibility of poisoning the pest or of destroying it by the use of machines, as well as investigating many of the features of its biology that were still absolutely unknown, were given careful attention by a specially trained assistant whose services were procured for that purpose. The results of the field work for this year were published in the form of a Farmers' Bulletin entitled "Methods of Controlling the Boll Weevil; Advice Based on the Work of 1902;" but on account of the late date of the establishment of the laboratory (June), and the consequent incompleteness of many of the records, it was not thought advisable to publish anything concerning the laboratory investigations. During

this season cooperation was carried on with the Mexican commission charged with the investigation of the boll weevil in that country, which was arranged on the occasion of a personal visit of Dr. L. O. Howard to the City of Mexico in the fall of 1901. Specimens of parasites were frequently exchanged, and through the courtesy of Prof. A. L. Herrera, chief of the Mexican commission, an agent in charge of the investigation in Texas visited the laboratories at the City of Mexico and Cuernevaca, where a study was made of the methods of propagating parasites, especially *Pediculoides ventricosus* Newp. A large number of specimens of this mite was brought back to Texas, where they were carried through the winter successfully and used in field experiments the following season.

The favorable reception by the planters of Texas of the experimental field work conducted during this season, with the increased territory invaded by the pest, brought about an enlarged appropriation for the work of 1903. By enactment which became effective on the 4th of March $30,000 was placed at the disposal of the Division of Entomology. It thus became possible to increase the number and size of our experimental fields as well as to devote more attention to the investigation of matters suggested by previous work in the laboratory. Seven experimental farms, aggregating 558 acres, were accordingly established in as many distinct cotton districts in Texas. Despite generally very unfavorable conditions the results of this experimental work demonstrated many important points. The principal ones are detailed in Farmers' Bulletin No. 189 of this Department.

DESTRUCTIVENESS.

Various estimates of the loss occasioned to cotton planters by the boll weevil have been made. In the nature of the case such estimates must be made upon data that is difficult to obtain and in the collection of which errors must inevitably occur. There is, of course, a general tendency to exaggerate agricultural losses, as well as to attribute to a single factor damage that is the result of a combination of many influences. Before the advent of the boll weevil into Texas unfavorable weather at planting time, summer droughts, and heavy fall rains caused very light crops to be produced. Now, however, the tendency is everywhere to attribute all of the shortage to the weevil. Nevertheless, the pest is undoubtedly the most serious menace that the cotton planters of the South have ever been compelled to face, if not, indeed, the most serious danger that ever threatened any agricultural industry. It was generally considered, until the appearance of the pest in Texas, that there were no apparent difficulties to prevent an increase in cotton production that would keep up to the enlarging demand of the world until at least twice the present normal crop of about 10,500,000 bales should be produced. Now, however, in the opinion of most authorities, the weevil has made this possibility very

doubtful, although the first fears entertained in many localities that the cultivation of cotton would have to be abandoned have generally been given up. An especially unfavorable feature of the problem is in the fact that the weevil reached Texas at what would have been, from other considerations, the most critical time in the history of the production of the staple in the State. The natural fertility of the cotton lands had been so great that planters had neglected completely such matters as seed selection, varieties, fertilizers, and rotation, that must eventually receive consideration in any cotton-producing country. In general, the only seed used was from the crop of the preceding year, unselected and of absolutely unknown variety, and the use of fertilizers had not been practiced at all. Although it is by no means true that the fertility of the soil had been exhausted, nevertheless, on many of the older plantations in Texas the continuous planting of cotton with a run-down condition of the seed combined to make a change necessary in order to continue the industry profitably.

A careful examination of the statistics, to which more complete reference is made in Farmers' Bulletin No. 189, has indicated that the pest causes a reduction in production for a few years after its advent of about 50 per cent, but at the same time it is evident that most planters within a few years are able to adopt the changes in the system of cultivating this staple that are made necessary by the weevil, so that the damage after a short time does not compare with that at the beginning. Upon the foregoing basis, during the season of 1903 the weevil caused Texas cotton planters a loss of about $15,000,000, and this estimate agrees rather well with estimates made in other ways by the more conservative cotton statisticians. A similar estimate made in 1902 led to the conclusion that the damage amounted to about $10,000,000. It consequently appears that during the years the pest has been in Texas the aggregate damage would reach at least $50,000,000. Many conditions of climate and plantation practice in the eastern portion of the cotton belt indicate that the weevil problem will eventually be as serious east of the Mississippi as it now is in Texas. According to the estimates of Mr. Richard H. Edmunds, the editor of Manufacturers' Record, the normal cotton crop of the United States represents a value of $500,000,000, the extreme ultimate damage that the pest might accomplish over the entire belt would be in the neighborhood of $250,000,000 annually, provided none of the means of avoiding damage that are now coming into common use in Texas were adopted. In spite of the general serious outlook, however, it must be stated that fears of the damage the weevil may do are very often much exaggerated, especially in newly invaded regions. It is not at all necessary to abandon cotton. The work of the Division of Entomology for several seasons has demonstrated that a crop can be grown profitably in spite of the boll weevil, and this experience is duplicated by many planters in Texas.

TERRITORY AFFECTED.

At the present time the boll weevil has not been found in the United States outside of Texas (see fig. 1) except in three instances in Louisiana. In one of these cases, at the sugar experiment station at Audubon Park, in the vicinity of New Orleans, the circumstances have led the State authorities to the conclusion that the pests were purposely placed in the fields. The other two cases are isolated occurrences in Sabine Parish, in the extreme western part of the State. Both of these are apparently traceable to importation from the opposite county in Texas, in cotton seed used for planting purposes or possibly in hay. The authorities totally destroyed the cotton growing at the experiment station at Audubon Park, La., as soon as the presence of the weevils was discovered. As no cotton is grown within 9 miles of that point, it seems altogether likely that the colony may have been completely exterminated. Similar action is being taken regarding the two colonies found in Sabine Parish.

In Texas the infested area extends from Brownsville, where the weevil originally entered the State, to Sherman. Shelby and Morris counties represent the extreme eastern range. The cotton acreage involved in this territory includes about 30 per cent of the cotton acreage of the United States, which produced in 1900 about 35 per cent of the total crop of this country, or about one-fourth of the crop of the world for that year. There is, however, a considerable belt between about the latitude of Dallas and the Red River where the pest does not occur in uniform numbers in all cotton fields, and consequently the general damage has not been great. It may be a matter of only two or three years before it will become sufficiently numerous to cut down the total production.

There are some features of special interest in the situation in Cuba. Although the weevil has long been known to occur in the island, it has attracted very little attention on account of the fact that the cultivation of cotton was abandoned for a long time in favor of crops that have been more profitable. Now, however, with the better price of the staple and rather unsatisfactory returns from some other crops, cotton is being planted upon a considerable scale. Mr. E. A. Schwarz was sent to the island on two occasions to study the conditions there. Although his report refers especially to the Province of Santa Clara, it is probably true that conditions similar to those he describes obtain everywhere. He found that the entire province is naturally more or less infested by the boll weevil, and that weevils did not spread from cultivated cotton planted with seed obtained in the United States to the wild plants, as at first supposed, but from the latter to the former. The weevils were found to be more numerous on the kidney cotton growing wild than on the loose cotton (seminiella). The latter, when growing alone, was usually found to be free from weevils, but liable to be infested when growing in the vicinity of kidney cotton. A large

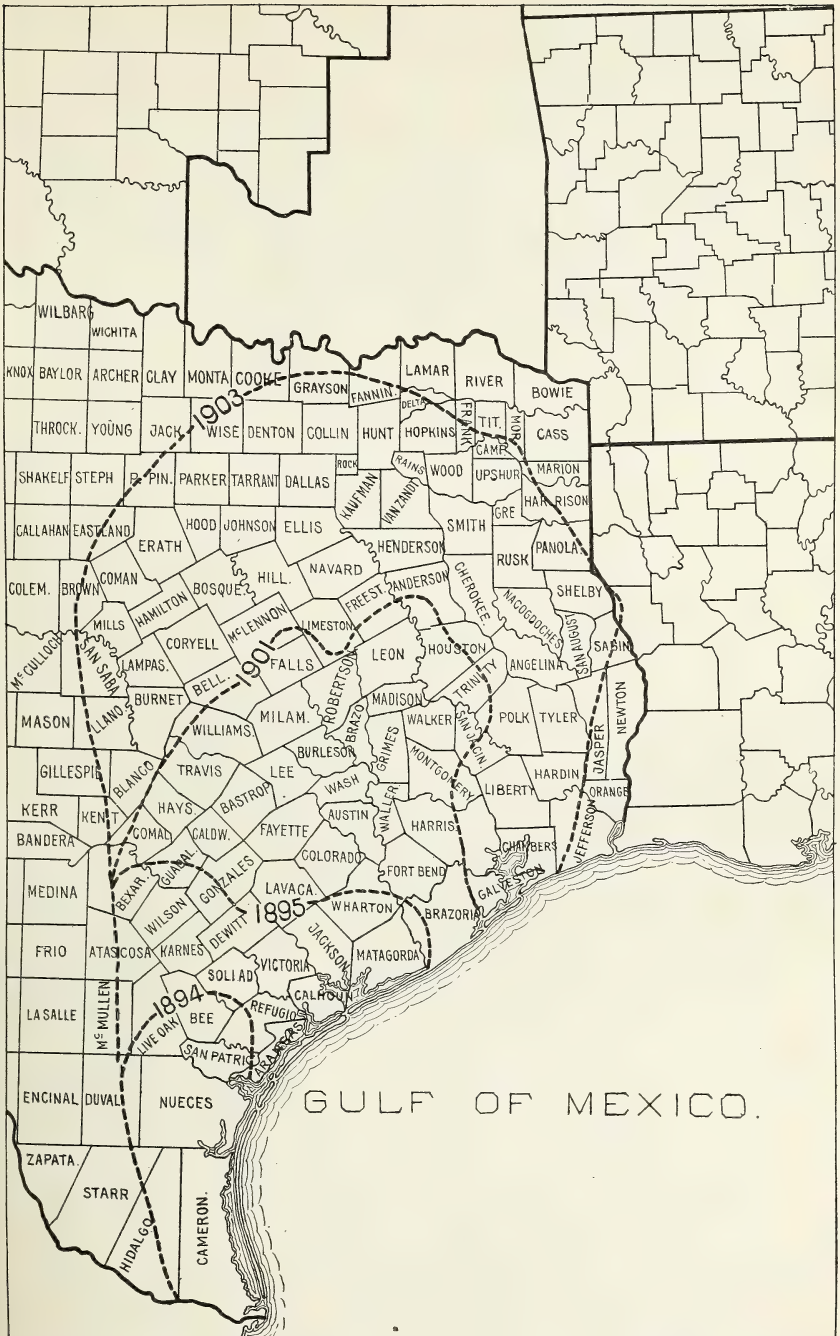


FIG. 1.—Map showing area infested by Mexican cotton boll weevil (redrawn.)

number of wild cotton trees growing in the vicinity of dwellings or growing entirely wild are always infested, and here the weevils are more numerous, but never as numerous as on the cultivated Egyptian cotton. At one locality, where a large number of kidney cotton trees were growing (about 50 plants, some of them probably 20 years old), it was found that at least one out of every twenty squares had been punctured by the first week in March. From Mr. Schwarz's report it does not seem that there is a very promising outlook for cotton raising in Cuba. The presence of wild perennial cotton, upon which the weevil probably exists everywhere, will always be a source of danger. The long moist seasons and mild winters will form more favorable conditions for the pest than will occur anywhere in the United States.

PROSPECTS.

The investigations of the life history of the weevil that are referred to in detail in the following pages have indicated that the most important elements in limiting the spread of an insect—namely, winter temperatures and parasites—in this case offer no assurance that the pest will soon be checked. For the past ten years, except where local unfavorable conditions have interfered, it has advanced annually a distance of about 50 miles. The insect is undoubtedly changing its habits and adapting itself to climatic conditions in new regions that it is invading. It is undoubtedly true that it has acquired an ability to withstand more severe frosts than occurred in the vicinity of San Antonio in 1895. Except in a few particular regions, however, it does not seem that the continued spread will be as rapid as it has been. The country between Gonzales County and the Red River is practically a continuous cotton field, and the prevailing winds have undoubtedly favored the northward spread of the insect. Similar conditions will now favor a rapid extension into the Red River valley in Louisiana, and likewise there seems no doubt that the spread will be rapid in the Yazoo valley in Mississippi; but in most other situations throughout the belt the cotton fields are smaller and more isolated than is the case in Texas; consequently it is to be supposed that the spread of the pest will be retarded somewhat.

Basing estimates on a careful study of the distance the boll weevil has traveled each year, as well as upon some attention that has been paid to the means whereby it reaches new territory, referred to more in detail hereafter (p. 94), it seems safe to predict that in from fifteen to eighteen years the pest will be found throughout the cotton belt. During the time it has been in Texas there has been no tendency toward dying out, and in south Texas the pest is practically as troublesome, except in so far as it is affected by changes in managing the crop, as it was in 1895. In Mexico, where it has existed for a much longer period, it is apparently as plentiful as ever. Careful attention that has been paid to the study of parasites and diseases, as well as

temperatures unfavorable to the insect, has failed to reveal any prospect that it will ever be much less troublesome than now. There will, nevertheless, be seasons from time to time in which the damage will be much less than normal. Climatic conditions will undoubtedly cause temporary diminution of the numbers of the pest in certain localities. In Texas these conditions have given rise almost every year to the supposition on the part of the planters that the insects have died out. This was especially the case in the region between San Antonio and Beeville in 1900, and in the vicinity of Corpus Christi in 1903. Both these years followed a series of seasons in which there was much less than the normal rainfall; consequently not only had a great many of the weevils been killed, but the numbers had been diminished by reason of the very limited extent to which it was possible to raise cotton. Both 1900 and 1903, however, were exceedingly favorable for cotton. Early planting was possible, and there was an abundance of rain throughout the season. The crop was so far advanced by the time the weevils became numerous that a very fair yield was made, although in neither of the cases was any top crop whatever produced. Whenever a series of years of scanty rainfall is followed by one of normal precipitation the weevil will temporarily be comparatively unimportant. The most disastrous seasons will be those in which the rainfall is excessive and planting unavoidably thrown late.

In this connection it becomes of some interest to speculate as to the possibility that the weevil may eventually be carried outside of the United States and gain a foothold in other cotton-producing countries. The fact that the insect is rather rapidly adapting itself to conditions in the United States that are quite diverse from those of its native home leads to the supposition that it would experience but little difficulty in adapting itself to climatic conditions wherever cotton may be grown. This probability of the spread of the weevil outside of the United States is increased by the fact that cotton seed for planting purposes is frequently shipped from the United States to various parts of the globe, and that within the last few years various conditions have caused especial interest to be displayed in this matter. There is nothing whatever to prevent weevils that may happen to be sacked with cotton seed from being carried long distances on shipboard. In the semidormant condition in which they hibernate they have often been known to go longer without food than is ordinarily required for a freight shipment from Galveston to Cape Town. Although there are no truly cosmopolitan cotton insects, it seems likely that the boll weevil may eventually be more widely distributed than any other.

LIFE HISTORY.

SUMMARY.

The egg is deposited by the female weevil in a cavity formed by eating into a square or boll. The egg hatches in a few days and the footless grub begins to feed, making a larger place for itself as it grows. During the course of its growth the larva sheds its skin at least three times, the third molt being at the formation of the pupa, which after a few days sheds its skin, whereupon the transformation becomes completed. These immature stages require on the average between two and three weeks. A further period of feeding equal to about one-third of the preceding developmental period is required to perfect sexual maturity so that reproduction may begin.

Variation in size depends directly upon abundance and condition of the food supply. Weevils of average size are about 8 mm. in length, one-third as broad as long, and weigh about one-fourth of a grain. Color varies as widely as does size. It is usually of a gray or yellow-brown, and is most markedly yellow in the largest weevils. Sexes are produced in practically equal numbers, the males predominating slightly. No other food has been found which will attract weevils from squares and no plant but cotton upon which they can sustain themselves for any considerable length of time. See Pl. II, fig. 12.

THE EGG.

The egg of the boll weevil is an unfamiliar object even to many who are thoroughly familiar with the succeeding stages of the insect. If laid upon the exterior of either square or boll it would be fairly conspicuous on account of its pearly white color. Measurements show that it is on the average about 0.8 mm. long by 0.5 mm. wide. Its form is regularly elliptical (Pl. III, fig. 14), but both form and size vary somewhat. Some eggs are considerably longer and more slender than the average, while others are ovoid in shape. The shape may be influenced by varying conditions of pressure in deposition and the shape of the cavity in which it is placed. The soft and delicate membrane forming the outer covering of the egg shows no noticeable markings, but is quite tough and allows a considerable change in form. Were the eggs deposited externally they would doubtless prove attractive to some egg parasite as well as to many predatory insect enemies. Furthermore, the density of the membranes would be insufficient to protect the egg from rapid drying or the effects of sudden changes in temperature. All these dangers the weevil avoids by placing the eggs deeply within the tissue of the squares or bolls upon which she feeds. As a rule, the cavities which receive eggs are especially prepared therefor and not primarily for obtaining food. Buried among the immature anthers of a square or on the inner side of one carpel of a boll, as they usually are, weevil eggs become very inconspicuous objects (Pl. I, fig. 3) and are found only after careful search.

EMBRYONIC DEVELOPMENT.

Owing to the transparency of the egg membranes, something of the development of the embryo can be seen through them, but no special study has yet been made upon the subject of the embryology of the weevil. The fully developed embryo completely fills the interior of the egg, its large head being in one end and its body curved ventrally upon itself till nearly double. Considerable motion is manifested if the egg be touched at this period.

LENGTH OF EGG STAGE.

Concealed as the eggs are beneath several layers of vegetable tissue, it is impossible to examine them to ascertain the exact length of the egg stage without in some degree interfering with the naturalness of the accompanying conditions. The beginning of the stage was easily obtained by confining female weevils with uninfested squares. Careful dissections were then made of the squares at a little later than what was found to be the average embryonic period at that season. In this way it is believed the range of error was reduced to a fraction of a day in most cases, and a large number of observations were made to still further reduce the error.

As shown by Table I, 553 observations have been recorded upon this point, the majority of the observations being made in the fall of 1902. Considering the temperatures prevailing at the four periods studied, it appears that the range in development during the average season at Victoria, Tex., has been included, and it seems probable that from these temperatures as a basis the length of the egg stage can be approximately determined for any season and for any locality within the present area of infestation.

TABLE I.—*Length of egg stage at certain periods.*

Period of examination.	Number of observations.	Mean temperature for period.	Average effective temperature.[a]	Average length of egg stage.
1902.		°*F.*	°*F.*	*Days.*
September 4–October 3	385	81	38	2.5 to 3
October 7–November 13	107	73	30	4 to 4.5
November 27–December 15	36	62	19	11
1903.				
May 27–June 5	25	72.5	32.5	3.5 to 4
Total	553			[b]3.4 to 4.1

[a] In considering the influence of temperature upon the weevils it has been assumed that, as has been found to be the case with other animals, 43° F. would be about the lowest temperature at which the weevils would be active. Temperatures below that point would have, therefore, no influence upon their activity, while all above that point would. For this reason it is better to speak of the "effective temperature," meaning by that the number of degrees above 43° F. Experiments made upon the influence of temperature upon the activity of weevils indicate that this is very near the correct figure for this insect.

[b] Weighted average.

The extreme range observed in Table II in the length of this stage is from two to fifteen days, while the average period for the whole

number of observations is but three and six-tenths days. It is possible that the embryo can undergo an even greater retardation without losing its vitality.

It may be noted here that drying of the square will also retard embryonic development, but this condition does not occur in the field.

TABLE II.—*Range in length of egg stage.*

Number of eggs.	Length of egg stage.	Number of eggs.	Length of egg stage.
	Days.		*Days.*
2	2	4	5 to 6
132	2 to 3	3	8 to 9
192	3	5	10 to 11
	2 to 4	15	10 to 12
42	3 to 4	4	10 to 13
96	4	3	13 to 14
	3 to 5	2	13 to 15
40	4 to 5		
13	5		
	4 to 6		

The length of the egg stage in bolls does not appear to differ greatly from that in squares.

HATCHING.

While still within the egg the larva can be seen to work its mandibles vigorously, and although a larva has never been seen in the act of making the rupture which allows it to escape from the egg, it is believed that the rupture is first started by the mandibles. The larvæ do not seem to eat the membranes from which they have escaped, but owing to the extreme delicacy of the skin it is almost impossible to find any trace of it after the larva has left it and begun feeding on the square.

HATCHING OF EGGS LAID EXTERNALLY.

It occasionally happens that females are unable to force an egg into the puncture prepared to receive it and the egg is left on the outside of the square or boll. Eggs so placed usually shrivel and dry up in a short time. To test the possibility of a larva making its way into a square from the outside, a number were protected from drying. Of the 19 eggs tested, 6 hatched in from two to three days. In no case, however, was the young larva able to make its way into the square and it soon perished. The hatching of eggs laid externally is of no importance, since the larvæ must perish without doing any damage.

EATING OF EGGS DEPOSITED OUTSIDE.

The number of eggs left outside increases as the female becomes weakened, and is especially noticeable shortly before her death. The number of such eggs which may be found is greatly diminished by the following peculiar habit, which was observed many times. Occasionally it appeared that the puncture which the female had made for the reception of an egg was too narrow to receive it, and after a prolonged attempt to force it down the female would withdraw her ovipositor,

leaving the egg at the surface. She would then turn immediately and devour the egg. After that, seeming conscious of her failure and aware of the cause of it, she would proceed to find and enlarge somewhat the cavity previously made. When this was completed she would attempt to place another egg therein. The second attempt was usually successful, but in one or two cases a female was seen to fail several times, and in more than half of these cases she ate the eggs, as has been described.

PERCENTAGE OF EGGS THAT HATCH.

Definite records were not kept upon this point, but in the many hundreds of eggs followed during these observations very few failed to hatch, though some were much slower in embryonic development than were others laid at the same time and by the same female. It is the writers' general impression that less than 1 per cent of the eggs are infertile or fail to hatch.

THE LARVA.

DESCRIPTION.

The young larva, upon hatching from the egg, is a delicate, white, legless grub of about 1 mm. ($\frac{1}{25}$ inch) in length. Except for the brown head and dark-brown mandibles, the young larva is at first as inconspicuous as the egg from which it came. As it feeds and grows it continues to enlarge a place for itself in the square or boll until the food supply has become exhausted or the vegetable tissues are so changed as to be unsuitable for food. By this time, as a rule, the interior of the square has been almost entirely consumed and the larval castings are spread thickly over the walls of the cavity (Pl. III, fig. 15). This layer becomes firmly compacted by the frequent turning of the larva as it nears the end of this stage. In the cell thus formed occur the great changes from the legless grub to the fully formed and perfect beetle (Pl. I, figs. 7, 8, and 9).

Throughout this stage the body of the larva preserves a ventrally curved crescentic form (Pl. III, fig. 16). The color is white, modified somewhat by the dark color of the body contents, which show through the thinner, almost transparent, portions of the body wall. The dorsum is strongly wrinkled or corrugated, while the venter is quite smooth. The ridges on the dorsum appear to be formed largely of fat tissue. After becoming full-grown the larva ceases to feed, the alimentary canal becomes emptied, and both the color and form of the larva are slightly changed. The dark color disappears from the interior and is replaced by a creamy tint from the transforming tissues within. The ventral area becomes flattened, and the general curve of the body is less marked. Swellings may be seen on the sides of the thoracic region, and when these are very noticeable pupation will soon take place.

GROWTH.

It is impossible to follow the growth of an individual larva without interfering so greatly with its normal conditions of life as to make the observations unreliable. It seemed more accurate to measure larvæ of approximately known ages. In these measurements the natural curve of the body was not interfered with, but the measurement taken across the tips of the body. In this way it was found that in squares during the hot weather the length of the body increases quite regularly by about 1 mm. a day. As it becomes cooler the daily growth is less. In bolls which grow to maturity the rate of growth is less and the length of the growing period is much greater. Full-grown larvæ vary in length from 5 to 10 mm. across the tips of the curve. Larvæ of normal size in squares average from 6 to 7 mm. The largest larvæ are developed in bolls which grow to maturity (Pl. III, fig. 19).

MOLTS.

To accommodate the rapid growth of the larva two or three molts occur. The period of change from one instar or stage to the next is so short that the chances of opening a square at just the right time to observe the process are very small indeed. However, it has been ascertained beyond question that two molts occur before the larva reaches half its growth. The first occurs at about the second day and the second at about the fourth day. Whether a third molt occurs before pupation can not be positively stated; but having occasionally found larvæ which had certainly just molted, but which were much larger than the usual size at the second molt, the writer is led to suspect that three larval molts may sometimes, though possibly they do not always, occur. In bolls where the length of the larval stage is often three or four times as great as that usually passed in squares it seems almost certain that more than two larval molts occur regularly. Counting only the first two molts which have been often found, a third occurs at the time the larva pupates.

PROCESS OF MOLTING.

So little is known in regard to the molting of Curculionidæ that the process as observed is here recorded. In the cases observed, starting at the neck, the skin split along the back, and was then pushed downward and backward along the venter of the larva. The cast head shield remained attached to the rest of the skin.

Immediately after casting the skin the head, as well as the rest of the body of the larva, was of a pearly-white color. The tips of the mandibles first became brown, and within a short time a yellowish-brown color marked the entire integument of the head.

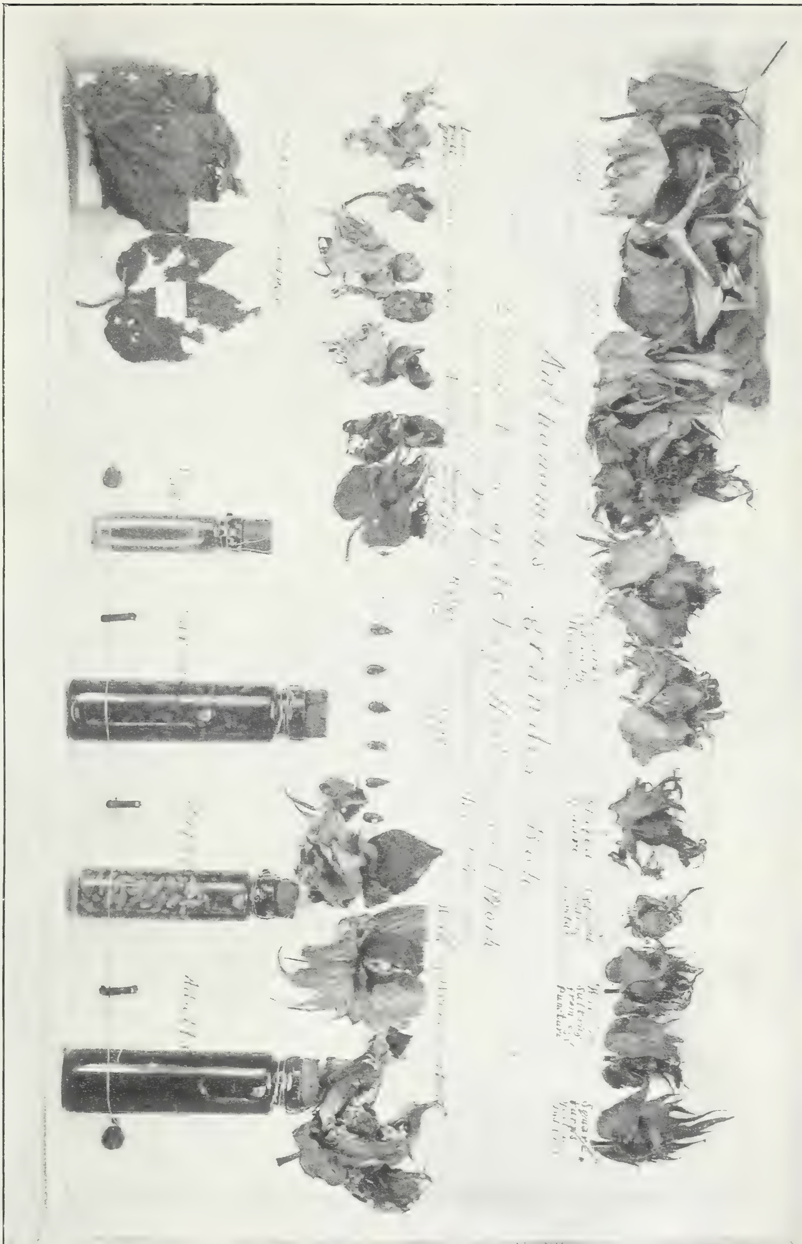
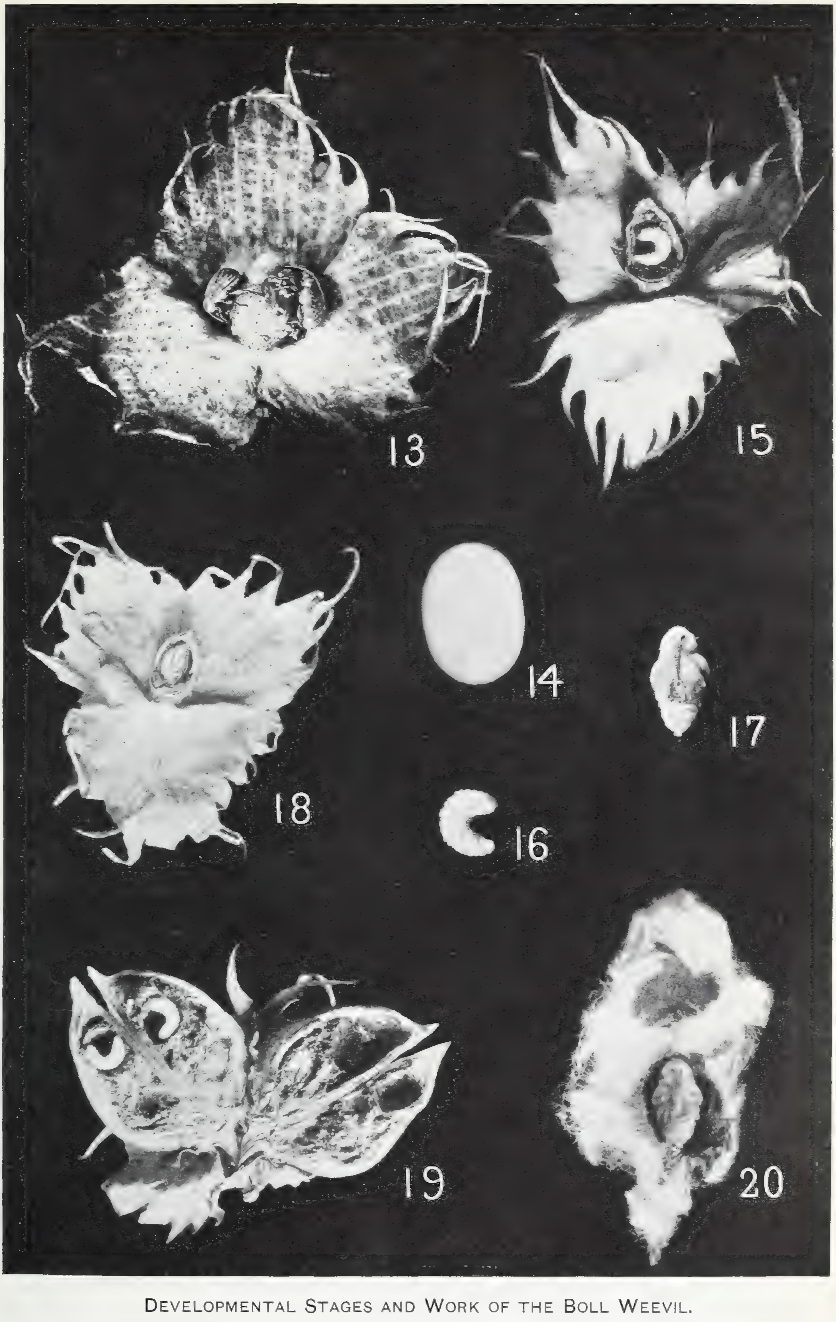


FIG. 12.—COLLECTION SHOWING LIFE HISTORY AND WORK OF BOLL WEEVIL. (ORIGINAL.)



DEVELOPMENTAL STAGES AND WORK OF THE BOLL WEEVIL.

Fig. 13, Two boll weevils feeding on a square, natural size; fig. 14, egg isolated, 25 times natural size; fig. 15, full-grown larva in square, natural size; fig. 16, full-grown larva isolated, natural size; fig. 17, pupa, twice natural size; fig. 18, adult just transformed, natural size; fig. 19, large larvæ in large boll, two-thirds natural size; fig. 20, pupal cell in boll, broken open, twice natural size. (Original.)

LENGTH OF LARVAL STAGE.

Most of the observations upon the larval stage were made between September 1 and December 15, 1902. The temperature prevailing during the first half of September was as high as is ordinarily experienced at Victoria during midsummer, and therefore the extremes of the average season may be considered as having been covered.

The time of egg deposition was easily determined by exposing uninfested squares in breeding cages containing active females. The time of hatching of the larva could only be found by opening the square, and it was so ascertained. The newly hatched larva was then placed in a small cavity made by lifting the covering on the side of a freshly picked square and removing one or two of the immature anthers. The coverings were then replaced as carefully as possible. Another disturbance was necessary to determine exactly the date of pupation. Observations made in this way were checked by others using larvæ which were allowed to go from egg deposition to pupation under natural conditions and without disturbance until the end of the larval stage was approximately reached. Since the sum of the times found for the various stages agrees approximately with the known length of the immature period in cases where no disturbance of normal conditions occurred, we may conclude that the periods found for the larval stage were approximately correct.

Altogether 266 observations were recorded upon the length of this stage. The majority of the observations may be included in three groups, and when thus grouped they may be best considered in relation to the effective temperature. Table III presents a brief summary of these groups:

TABLE III.—*General results as to length of larval stage in squares.*

Period of examination.	Mean average temperature.	Average effective temperature.	Number of observations.	Average range of stage.
1902.	°*F.*	°*F.*		*Days.*
September 6 to October 5	78.7	35.7	195	6 to 9
September 26 to October 21	73.6	30.6	15	7 to 12
November 11 to December 12	62.5	19.5	15	20 to 30

During the heat of summer the larval stage requires approximately one week. This time appears to hold so long as the mean average temperature remains above 75° F. As the temperature falls below that point there is a gradual increase in the length of this stage. The average total effective temperature required during hot weather by the larval stage is not far from 280° F. As development becomes retarded by colder weather the average total effective temperature required to complete it is much greater.

These facts may be expressed in general by stating that during the hottest summer weather the length of this stage is somewhat less than

one week. Development becomes slower as the temperature falls, but does not cease altogether so long as cotton can live. Even frosts do not destroy larvæ in the squares and bolls, and these may finish development during warmer weather after the frost has taken place.

The length of the larval stage in bolls is as a rule much greater. If the boll falls when small the increase is slight, but if an infested boll grows on to maturity the larval stage more than any other is much extended. Special observations upon the larval stage in bolls have not been made, but reckoning from the known length of the whole developmental period in maturing bolls we may conclude that the larval stage can not be less than six or seven weeks.

PUPAL CELLS IN BOLLS.

As the boll approaches maturity, the full-grown larva ceases to feed upon the drying and hardening tissues of seed and fiber. Its excrement, more or less mixed with lint, becomes firmly compacted, and in the drying which occurs the mass forms a cell of considerable firmness, within which pupation and the subsequent transformation to the adult take place (Pl. III, fig. 20). These pupal cells frequently include a portion of the hull of a seed, but the writer has never found a large larva or a pupa entirely inclosed within a single cotton seed. The cells described are shorter and thicker than seeds, but in general appearance there is considerable resemblance between them (Pl. XI, fig. 44). Doubtless these cells have misled some into the statement that they have found weevils in cotton seeds.

PUPATION.

The formation of the adult appendages has gone a good way before the last larval skin is cast. The wing pads appear to be nearly half their ultimate size. The formation of the legs is also distinctly marked, and the old head shield appears to be pushed down upon the ventral side of the thorax by the gradual elongation of the forming proboscis. Finally the tension becomes so great that the tightly stretched skin is ruptured over the vertex of the head, and it is then gradually cast off, revealing the delicate white pupa. The cast skin frequently remains for some time attached to the tip of the abdomen.

THE PUPA.

When this stage is first entered the insect is a very delicate object both in appearance and in reality. Its color is either pearly white or cream. The sheaths for the adult appendages are fully formed at the beginning of the stage and no subsequent changes are apparent except in color (Pl. I, figs. 5 and 6). The eyes first become black, then the proboscis, elytra, and femora become brownish and darker than the other parts (Pl. III, fig. 17).

The final molt requires about thirty minutes. The skin splits open over the front of the head and slips down along the proboscis and back over the prothorax. The skin clings to the antennæ and the tip of the proboscis till after the dorsum has been uncovered and the legs kicked free. Then by violently pulling upon the skin with the fore legs first the tip of the snout and then the antennæ are freed, and finally the shrunken and crumpled old skin is kicked off the tip of the abdomen by the hind legs.

LENGTH OF PUPAL STAGE.

The length of this stage is more easily determined than that of any other. It seemed to make little difference in the time whether the pupæ were allowed to remain in the squares or removed therefrom. Considerable variation in the length of this stage exists among individuals of the same generation and even between offspring of the same female and from eggs laid on the same day. The period of investigation ranged from July to December, so that the extremes of the season are included. Altogether over 450 observations were made upon the length of this stage. Nearly all of these are included in Table IV, which shows a summary of the results.

TABLE IV.—*Tabular arrangement of observations upon the length of pupal stage in squares.*

Period of examination.	Number of observations.	Range in length of pupal stage.	Average length of stage.	Average effective temperature.	Total effective temperature.
1902.		*Days.*	*Days.*	° *F.*	° *F.*
July 6 to 31	161	2 to 5	3.5	39.65	138.8
September 15 to October 3	81	3 to 7	5.2	36.05	187.5
September 24 to October 28	167	4 to 8	6.0	31.1	186.1
November 2 to 13	29	5 to 6	5.6	26.2	146.7
December 2 to 29	4	10 to 16	14.5	18.55	269.0

It should be noted in connection with Table IV that the observations made in November were during a period of rather warm weather and that the temperature records for that time are incomplete. It is likely that the average effective temperature given for that period might be different were the records complete.

The average length of this period during hot weather is from three to four days, and the period increases as the cool fall weather approaches to a maximum of about fifteen days.

A comparison of Tables I, III, and IV shows that the decrease in temperature affects each stage in very nearly the same proportion. In each case the maximum recorded length of any stage is about four times its minimum, and the great retardation in each case occurs somewhere between 60° and 70° F. of mean average temperature, or 17° to 27° F. of effective temperature. Even greater retardation occurs during the winter season.

The length of the pupal stage in large bolls has not been determined. It appears to be longer than in squares, but it certainly can not occupy the same proportional part of the entire developmental period that it does in squares.

EFFECT OF BURYING SQUARES UPON PUPATION AND THE ESCAPE OF ADULTS.

The experiments made upon this point were designed to ascertain the value, if any, in the plowing under of squares as a means of destroying the larvæ and pupæ infesting them. But few experiments seemed necessary to demonstrate the futility of this operation alone as a means of controlling the weevil.

Squares which were known to be infested with about half-grown larvæ were placed in glass jars and covered with several inches of quite dry and fairly well pulverized earth. When examination was made it was found that pupation had taken place normally while the squares were buried under from 2 to 5 inches of dirt. In no case was pupation prevented, though a few weevils did not leave the squares after having become adult. Altogether about 100 squares were thus buried, and from them over 75 weevils emerged.

In a portion of the preceding tests careful examination was made to ascertain how far toward the surface the newly emerged weevils had succeeded in getting before they perished. It should be noted that these weevils had never fed, and they would have, therefore, less strength and endurance than such fully hardened adults as might be buried in the ordinary processes of field cultivation. Furthermore, the soil used was of finer texture and more compactly settled than it would be in the field. Twenty-seven weevils were found in this examination, their location varying from the bottom of the jar to their having escaped through 4 inches of soil. A weighted average shows, however, that each weevil had made its way upward through 2 inches of dirt. We may infer, therefore, that had these squares been buried under less than 2 inches of fairly well pulverized earth, as would be the case from field cultivation, but a small percentage of them would have failed to make their way out. As it was, fully three-fourths of those leaving the squares made their way out through more than 2 inches of dirt.

In 1896 Mr. C. L. Marlatt noted that "the weevils can escape from loose soil when buried to a depth of 3 inches, but when artificially embedded 8 inches in moist soil they are unable to extricate themselves, as shown by test experiment." Quite extensive experiments are now being made at Victoria to test the ability of the fully fed adult weevils to escape after being buried at various depths and in soil containing various percentages of water. That the moisture content exerts a great influence upon the texture of the soil is especially noticeable in the black bottom lands of the Texas cotton belt. While

the results of these experiments may furnish reasons for changing our conclusions upon this point, the present indication is that the beneficial effect of thorough cultivation lies in the direct influence which that practice exerts upon the steady and rapid growth of the cotton, thus favoring the production of squares, the setting of bolls, and the early maturity of the crop rather than in the direct destruction of the weevils by burying them either while in the squares or after they have become adult.

THE ADULT.

BEFORE EMERGENCE.

Immediately after its transformation from the pupa the adult is very light in color and comparatively soft and helpless. The proboscis is darkest in color, being of a yellowish brown; the pronotum, tibiæ, and tips of the elytra come next in depth of coloring. The elytra are pale yellowish, as are also the femora. The mouth parts, claws, and the teeth upon the inner side of the fore femora are nearly black. The body is soft and the young adult is unable to travel (Pl. III, fig. 18), consequently this period is passed where pupation occurs. Usually two or more days are required to attain the normal coloring and the necessary degree of hardness to enable the adult to make its escape from the square or cell.

EMERGENCE.

The normal method of escape from squares and small bolls is by cutting with its mandibles a hole just the size of the weevil's body (Pl. IV, fig. 21). In large bolls the escape of the weevil is greatly facilitated by the natural opening of the boll (Pl. IV, fig. 22). Often the pupal cell is broken open by the spreading of the carpels, and when this is the case the pupa, if it has not already transformed, becomes exposed to the attack of enemies or, what is probably a more serious menace, the danger of drying so as to seriously interfere with a successful transformation. If the cell remains unbroken the weevil always escapes by the path of least resistance, cutting its way through as in the case of a square (Pl. IV, fig. 26). The material removed does not appear to be eaten, but is rather cast aside and left within the cell as a mass of fine débris.

CHANGES AFTER EMERGENCE.

At the time of emergence the weevils are comparatively soft, and they do not attain their final degree of hardness for some time after they have begun to feed. If they never feed they never harden. The color of the chitin is of an orange tinge at the time the weevils leave the squares or bolls, but after exposure for some time it turns to a dark chocolate brown. The development of the hair-like scales is probably entirely checked by the drying of the chitin, but the

darkening of the ground color makes the scales more apparent, and thus gives the impression of further development after emergence has taken place.

SIZE OF WEEVILS.

Size of boll weevils is an especially variable quantity, and, as usual, varies almost directly in proportion to the abundance of the larval food supply and the length of the period of larval development. The extremes are so great that the smallest and largest weevils would be thought by one not thoroughly familiar with them to be of entirely different species. So far as dimensions may convey an idea of the size, we may say that the weevils range from 3 to 8 mm. ($\frac{1}{8}$ to $\frac{1}{3}$ inch) in length, including the proboscis extended, and from 1 to 3 mm. ($\frac{1}{25}$ to $\frac{1}{8}$ inch) in breadth at the middle of the body. (See Pl. I, fig. 1.)

RELATION OF SIZE TO FOOD SUPPLY.

The smallest weevils are developed from squares which were very small, and which, for some reason, either of plant condition or of additional weevil injury, fell very soon after the egg was deposited. The supply of food was not only small, but, owing to the immaturity of the pollen sacs, its quality was also poor. Normally squares continue to grow for a week or more after eggs are deposited in them, and such squares produce the weevils of average size and color.

The largest weevils are produced in bolls which grow to maturity. In them the food supply is most abundant, and the period of larval development is several times as long as it is in squares. Possibly these differences in size may be better shown by a summary of observations which were made upon the weight of adults.

WEIGHT OF ADULTS.

The weevils used in these experiments were bred to insure their coming from the proper source. After emergence they were fed for some time to bring them up to their normal weight.

Table V.—*Summary of weight of weevils.*

Source of weevils.	Number.	Average weight.
		Grain.
Bred from picked small squares	25	0.105
Bred from average fallen squares	68	.231
Bred from large bolls	69	.268
Total	162	36.825
Average weight per weevil, all sources		.227

It should be noted that these figures do not nearly represent the weight of the extremes in size, but they do indicate the difference in the average weevil of each class.

COLOR.

Color is very often a variable character in insects, and the boll weevil presents considerable range in this respect. Whatever influences the size of the larva affects directly the size of the adult, and it is noticeable that weevils of the same size are also, as a rule, closely alike in color. In general, the smaller the size of the weevil the darker brown is its color; the largest weevils are light yellowish brown. Between these two extremes are the majority of average-sized weevils, which are either of a gray-brown or dark yellow-brown color. Weevils developing in large bolls, having an abundant food supply and a developmental period averaging more than twice that of weevils in squares, are larger in size and more yellowish in color than are those from squares.

The principal reason for the variation in color lies in the degree of development of the minute hair-like scales, which are much more prominently developed in the large than in the small specimens, although the color of old specimens is often changed by the rubbing off of the scales. The scales are yellow in color, while the ground color of the chitin bearing them is a dark brown or reddish brown. When the scales are but slightly developed, as seems to be the case with small weevils produced from underfed larvæ, the dark-brown ground color is predominant, while in the case of large weevils produced from larvæ having abundant food and a long period of development the scales are largely produced and give the strong yellow tone to the color which is characteristic of them.

The development of the scales appears to take place mostly after the adult weevil has become quite dark in color but before it becomes fully hardened. They seem, therefore, to be a sort of non-essential aftergrowth which depends upon the surplus food supply remaining after the development of the essential parts of the weevil structure.

SIZE AND COLOR NOT INDICATIVE OF SEX.

Eminent coleopterists have studied the boll weevil most carefully with the purpose of discovering some external character by which the sexes could be distinguished, but all have failed to find any reliable points of distinction. The writer therefore does not hesitate to own that he also has failed to find any reliable character for the distinction of the sexes. Many persons have the idea that the small dark weevils are males and the larger and lighter-colored brownish-yellow weevils are females. This idea is a mistaken one. In general it is probably true that the males are slightly smaller than the females, but judging from determinations of the sex of many hundreds of weevils it may be stated positively that size and color are characters which are related to food supply and length of the period of development and are not indications of sex. The sexes seem to be about equally represented among the smallest as well as the largest weevils.

Characters commonly used to separate the sexes in the family Curculionidæ are not distinctive in this species. As a rule the antennæ are inserted nearer the tip of the snout in the male than in the female. This character is variable among boll weevils; and though a large number of accurate measurements might show that a slight difference generally exists, it is too inconspicuous a character to be of general use. With most species the top of the rostrum of the male is rougher than is that of the female. However it may be with other species, there is but little if any difference in this respect between the young adults of the boll weevil. As the individuals become older the greater activity of the females serves to wear the roughness from the top of the rostrum, and thus gradually, as a result of different habits, this character becomes more distinctive. In less than half of the boll weevils, however, is this character sufficiently noticeable to separate the sexes. The terminal segment of the abdomen shows no external difference in either sex, although in many weevils important characters are there found.

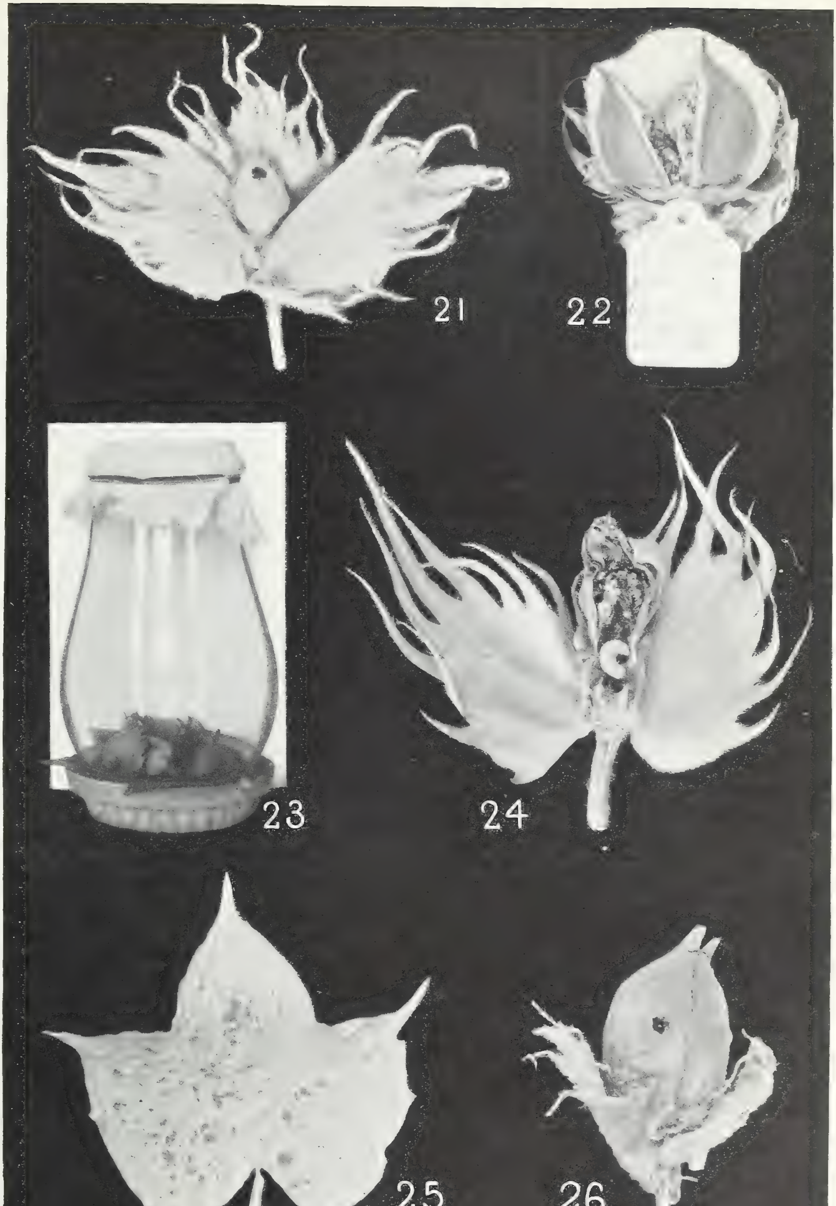
PROPORTIONS OF THE SEXES.

No reliable secondary sexual characters having as yet been discovered, the certain determination of sex therefore rests solely upon the primary characters, thus requiring a certain amount of dissection in each case. Such determinations have been made upon large numbers of weevils taken in the field and upon many bred in the laboratory at various seasons of the year. The results are briefly summarized in Table VI.

TABLE VI.—*Proportions of the sexes.*

	Number of males.	Number of females.
Season of 1902, both bred and from field	240	260
Hibernated weevils, 1902–3	269	174
First generation, 1903	43	32
Bred weevils, 1903	45	33
Field weevils, midsummer, 1903	52	59
Total	649	558

From these 1,207 determinations it appears that males are somewhat more numerous than females, the percentage being nearly 54 of males to 46 of females. It is noticeable, however, that the only season at which a preponderance of males occurs is during late fall. If we exclude the figures for hibernated weevils for a moment, we find that the totals for the balance of the season are remarkably close for the two sexes, being 380 males and 384 females. It seems safe to say, therefore, that the sexes are practically equal in numbers except that more males than females seem to be found among hibernating weevils. It may be that the retardation of development due to approaching



BREEDING JAR AND METHOD OF ESCAPE OF ADULTS FROM SQUARES AND BOLLS.

Fig. 21, Emergence hole made by weevil in square, natural size; fig. 22, weevil escaping normally from boll, two-thirds natural size; fig. 23, apparatus used in breeding weevils, one-fourth natural size; fig. 24, larva destroying the ovary and preventing the bloom in large squares, natural size; fig. 25, leaf fed upon by weevils in confinement, one-half natural size; fig. 26, emergence hole of weevil from boll which never opened, two-thirds natural size. (Original.)

FIG. 27.—LARVA IN SQUARE, OVARY UNTOUCHED, NATURAL SIZE. (ORIGINAL).

FIG. 28.—LARGE AND SMALL LARVÆ IN BOLL, TWO-THIRDS NATURAL SIZE. (ORIGINAL.)

cold weather favors the development of males. Not only was there a larger number of males than of females taken in December, 1902, but there were also more males than females taken in the field in the spring of 1903 among the hibernated weevils which lived through the winter. According to the determinations made, 64 per cent of the 259 weevils dying during the winter were males and 56 per cent of the weevils living through the winter were also males. Since it appears that females require fertilization in the spring before they begin to deposit eggs, the preponderance of males at that time acts as a provision to insure the propagation of the species.

LENGTH OF LIFE UPON SQUARES.

The observations made along this line may be divided into eight groups, each dealing with some special food condition or class of weevils. For the confinement of weevils in the laboratory the most satisfactory apparatus tried, both for convenience in handling and for the maintenance of favorable conditions for the weevil, was made up as follows: A 4 or 5 inch shallow earthen saucer, such as is used with flowerpots, was filled with soil, which was kept fairly moist. Over this was placed a fresh cotton leaf, which conserved the moisture from the soil, but never became wet, and kept both weevils and squares clean, besides facilitating the handling necessary to frequent renewals of the food supply and the consequent transference of the weevils. The rest of the cage was formed by an ordinary lantern globe covered at the top by cheese cloth held firmly in place by a rubber band. With this apparatus weevils could be readily observed without disturbing them, and food supplied was kept in good condition and could be easily renewed, while there were no cracks to hide in or to allow weevils to escape (Pl. IV, fig. 23). The moisture of the soil and fresh leaf covers were renewed as needed. Clean squares were supplied each day, and the actual number of egg and feeding punctures recorded upon numbered slips kept with each cage. The sex of each weevil was also determined and noted upon its death, thus giving an accurate record of the number and sex of weevils responsible for the punctures recorded. Most of the weevils used were bred, so that the exact length of their lives is known. Length of life refers only to adult life from the time of emergence from the square or boll to the death of the weevil. Many weevils brought in from the field were under observation in the laboratory for periods sufficiently long to justify the inclusion of the results obtained from them with those of weevils which were bred. Obviously the time these were under observation does not represent their true length of life; therefore the inclusion of both results renders the averages obtained the more conservative.

TABLE VII.—*Length of life of weevils upon squares.*

	Males.		Females.	
	Number.	Average days.	Number.	Average days.
Weevils placed in hibernation Dec. 15, 1902; living Apr. 15, 1903	23	180	14	171
Hibernated weevils taken spring, 1903; estimated adult Dec. 15, 1902	66	223	53	220
Hibernated weevils, from time of feeding in 1903	{ 23 67	57 88	16 52	37 80
First generation, bred	30	58	25	56
Third generation, bred	18	43	10	54
Fifth generation, bred	9	76	9	54
Totals and weighted averages, including hibernation period	146	151	111	148
Totals and weighted averages, not including hibernation period	147	71	112	64
Entire length of life, hibernated weevils only	89	212	67	210

Whether we include the time of hibernation or not, it appears from the averages of 156 hibernated weevils that those which winter successfully are longer lived than any following generation, as their active life in spring averaged fully 80 days for males and 70 for females. Probably the greater activity of the first generation may account for their somewhat shorter life. The average active life period for all generations is probably not far from 71 days for males and 64 days for females.

LENGTH OF LIFE ON BOLLS ALONE.

As weevils appear to feed freely on bolls in the field after the period of maximum infestation has been reached (Pl. I, fig. 10), these tests were made to determine whether they might be able to live normally with no other food.

A number of weevils were placed upon bolls as soon as they became adult. Others which had first been fed upon squares were given bolls after they had become hard and had shown themselves to be in a normally healthy condition. Of the total 37 weevils thus tested, 16 were males and 21 were females. The males showed an average length of life of 19.7 days, while the females survived for only 15.2 days. This is a much shorter period than the normal length of life upon squares for either sex.

LENGTH OF LIFE ON COTTON LEAVES ALONE.

To determine whether they could live upon the foliage of cotton alone 69 newly transformed weevils were at the 1st of October, 1902, placed upon fresh leaves, which were renewed at frequent intervals. During the first three weeks 52 of these weevils (21 male and 31 female) died, leaving 17 alive and well; 11 of these were then returned to squares and 6 continued upon the leaves. Of these 6, 3 lived to be 81 days old and were then intentionally killed for dissection. The

average length of life of those kept entirely upon leaves was over 30 days. These results show clearly the ability of many of the weevils to live upon foliage alone in fields in which fall grazing is practiced until it becomes sufficiently cold for them to go into winter quarters (see Pl. IV, fig. 25).

LENGTH OF LIFE WITH SWEETENED WATER AND WITH MOLASSES.

So much has been said about the attraction of molasses for the weevils that tests were made with a cheap grade of molasses diluted with from 20 to 25 parts of water to see whether this solution really served them as food. The weevils used were just adult and had taken no other food. They fed quite readily upon the solution, remaining quietly with their snouts in the water for from a few minutes to an hour and a half at a time. The solution did not seem to draw them from any distance, but as soon as a weevil came to it it would stop to drink. Feeding or drinking took place daily or oftener until the death of the weevils. The average length of life for the 12 weevils used was a little less than 6 days.

As weevils without food but with water lived an average of 5½ days, the conclusion is that a solution of molasses 1 to water 25 parts does not serve the weevil as food, since it does not noticeably prolong life.

Six weevils just emerged kept upon undiluted molasses showed a greater length of life, these dying at an average age of 11½ days.

LENGTH OF LIFE WITHOUT FOOD, BUT WITH WATER.

These observations were made during August as a check upon those without water. The 8 weevils used were just adult and had never fed. Each weevil drank for one or two minutes at least once each day so long as it lived. All died at nearly the same time, having lived for an average of about 5½ days. As those without water lived an average of 5 days, it appears that access to water in the absence of food does not materially increase the length of life of the starving weevils.

LENGTH OF LIFE WITHOUT FOOD OR WATER.

Three series of observations were made along this line. In the first the weevils used were taken immediately after emergence and never allowed to feed. Fifty weevils were tested in this way during July and August and showed an average length of life of 5 days from the date of emergence. A few lived as long as 8 or 9 days. These never acquired as dark a color nor as great a degree of hardness as is normal.

In the second series the 15 weevils used were 7 weeks old and full-fed at the time of beginning the test. These showed an average length of life of slightly over 6 days, the range being from 5 to 9 days. These weevils were tested during the latter half of November, and the late-

ness of the season, together with the full-fed condition of the weevils, seemed to promise a considerably longer period than 6 days.

In the third series the 18 weevils used were 1 month old and full-fed at the beginning of the test in the middle of November. The conditions in this series were as in the series preceding, with the exception that an abundance of two species of grass taken from cotton fields was included. These weevils showed an average length of life of nearly 7½ days, ranging from 3 to 10 days. The weevils made no effort to feed upon the grass, so the slightly longer life period must be due to other causes.

CANNIBALISM.

It is hardly proper to speak of cannibalism as a food habit of the boll weevil, but the facts observed may well be recorded here. Under the impulse of extreme hunger weevils have several times showed a slight cannibalistic tendency.

Seven beetles were confined in a pill box without food. On the third day 6 only were alive. Of the seventh only the hardest chitinized parts (head, proboscis, pronotum, legs, and elytra) remained, the softer parts having been eaten by the survivors.

In another box containing 12 adults the leaf supplied for food was insufficient, and on the fourth day 8 were dead, 4 were partly eaten, and others had lost one or more legs each.

In another case a few young adults and a number of squares containing pupæ were placed in a box together with a few fresh squares to serve as food for the adults. When the box was opened after a number of days, one "reddish-brown" adult was found having its elytra eaten through and most of its abdomen devoured. In spite of this mutilation the victim was still alive and kicking slowly. The squares were still fresh and fit for food, so that this is really the clearest case of cannibalism observed.

Frequently more than one larva hatches in a square, and when this is the case a struggle between them is almost certain to take place before they become full grown. Many cases have been observed in which squares contained one living and one or more smaller dead larvæ, while in a few cases the actual death struggle was observed.

HABITS.

Among the habits of any insect of economic importance, the first for careful study are those relating to its food, and secondly those connected with its propagation. The study of the life history of the boll weevil has revealed no especially vulnerable point, but rather the important fact that in all its stages it is better protected against the attacks of enemies and the ordinarily effective remedies recommended by the economic entomologist than any other insect which has ever threatened the production of any of the great staple crops of this

country. Naturally, then, we must needs turn to a study of the habits of the pest to point the way to means by which either it may be itself destroyed or its great destructiveness prevented.

FOOD HABITS.

LARVAL.

It is plainly the intention of the mother weevil to deposit her egg so that the larva upon hatching will find itself surrounded by an abundance of favorable food. In the great majority of cases this food consists principally of immature pollen. This is the first food of the larva which develops in a square, and it must be both delicate and nutritious. Often a larva will eat its way entirely around a square in its pursuit of this food. In most cases the larva is about half grown before it feeds to any extent upon the other portions of the square. It may then take the pistil and the central portion of the ovary, scooping out a smoothly rounded cavity for the accommodation of its rapidly increasing bulk (Pl. I, fig. 7; Pl. III, fig. 15; Pl. IV, fig. 24). So rapidly does the larva feed and grow that in rather less than a week it has devoured two or three times the bulk of its own body when fully grown. It sometimes happens that the square is large when the egg is deposited therein, and the bloom begins to open before the injury by the larva is sufficient to arrest its development. In many cases of this kind the larva works its way up into the corolla and falls with it, leaving the young boll quite untouched (Pl. V, fig. 27). Occasionally the flower opens and fertilization is accomplished before any injury is done the pistil, and in rare cases a perfect boll results from a truly infested square. Sometimes the larva when small works its way down into the ovary before the bloom falls, and in such cases the boll falls as would a square.

In large bolls the larvæ feed principally upon seed and to some extent upon immature fiber. A larva will usually destroy but one lock in a boll, though two are sometimes injured (Pl. V, fig. 28).

ADULT.

Before escaping from the square the adult empties its alimentary canal of the white material remaining therein after the transformation. The material removed in making an exit from the cell is not used as food, but is cast aside. Weevils are ready to begin feeding very soon after they escape from the squares or bolls in which the previous stages have been passed. For several days thereafter both sexes feed almost continuously and seem to have no other purpose in life. They will take squares, bolls, or leaves, but they much prefer the squares, and when squares are present in the field it is probable that leaves are seldom touched. As has been shown, however, weevils can live for a long time upon leaves alone when squares and bolls are

wanting. Bolls are only slightly attacked so long as there is an abundance of clean squares.

The method of feeding is alike in both sexes. The mouth-parts are very flexibly attached at the tip of the snout (fig. 2) and are capable of a wide range of movement. The head fits smoothly into the prothorax like the ball into a socket joint and is capable of a considerable angle of rotation. The proboscis itself is used as a lever in prying and helps to enlarge the puncture through the floral envelopes especially. Feeding is accomplished by a combination of movements. The sharply toothed mandibles serve to cut and tear, while the rotation of the head gives the cutting parts an auger-like action. The forelegs especially take a very firm hold upon the square and help to bring a strong pressure to bear upon the proboscis during certain portions of the excavating process. The outer layer of the square, the calyx of the flower, is naturally the toughest portion that they have to penetrate, and only enough is here removed to admit the snout. After that is pierced the puncture proceeds quite rapidly, combinations of chiseling, boring, and prying movements being used. While the material removed from the cavity is used for food, the bulk of the feeding is upon the tender, closely compacted, and highly nutritious anthers or pollen sacs of the square. When these are reached the cavity is enlarged, and as much is eaten as the weevil can reach. The form of the entire puncture becomes finally like that of a miniature flask.

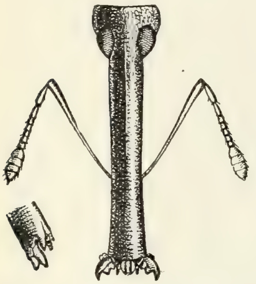


Fig. 2.—Mexican cotton boll weevil, head showing rostrum with antennæ near middle and mandibles at end—much enlarged (original).

Only after weevils have fed considerably do sexual differences in feeding habits begin to appear (Pl. III, fig. 13), the females puncturing mainly the base and the males the tip of the square.

Feeding punctures are much larger and deeper than are those made especially for the reception of the eggs (Pl. I, fig. 3); more material is removed from the inside of the square or boll and the opening to the cavity is never intentionally closed. Feeding punctures are most frequently made through the thinner portion of the corolla not covered by the calyx. The exposed tissue around the cavity quickly dries and turns brown from the starting of decay. As a number of these large cavities are often formed in one square (Pl. VI, fig. 29), the injury becomes so great as to cause the square to flare immediately, often before the weevil has ceased to feed upon it. Squares so severely injured fall in a very short time. The injury caused by a single feeding puncture is often overcome by the square and its normal course of development is continued. When feeding punctures are made in squares which are nearly ready to bloom, the injury com-

monly produces a distorted bloom (Pl. VI, fig. 30) and in very severe cases the boll will drop soon after setting.

After the females begin to oviposit their feeding habits become quite different from those of the males. Up to this time both sexes move but little, making a number of punctures in a single square; but from this point we must consider the feeding habits of the sexes separately.

MALE.

Studies of the feeding habits of males have been made both in the laboratory and out of doors. In the laboratory 65 males were under observation during a total period of 2,492 weevil-days.[a] During this period 2,185 squares were supplied them and they made 5,617 feeding punctures in 1,582 of these squares. A little calculation shows that they averaged to make $3\frac{1}{2}$ feeding punctures in each square, at the rate of $2\frac{1}{4}$ punctures a weevil each day. These observations were in most cases made during the latter part of each weevil's life. During the first few days they have often been found to make from 6 to 9 punctures a day. A general average of 3 feeding punctures a day in the laboratory would seem to be near the actual figures during the warm weather.

As each male while under observation attacked only about 2 squares every 3 days, the destructiveness of males seems comparatively slight.

Five males were followed upon plants under a field cage for a total period of 145 weevil-days. During this period they attacked 68 squares, making therein a total of 177 feeding punctures. This means an average of 2.6 punctures per square and an average of 1.2 punctures per male per day, making the number of squares attacked by each male less than 1 every 2 days. These outdoor observations indicate that the laboratory results, small though they appear, are yet higher than the actual field numbers. Whether in or out of doors, the activity of feeding decreases as the male grows older.

Males choose to puncture more often than do females through the tip portion of the square not covered by the calyx. The yellow or orange colored excrement is abundant, and owing to the somewhat sedentary habits of the males it accumulates often in quite large masses.

FEMALE.

After they begin to oviposit females seem generally to feed less upon one square or in one puncture than they do previous to that time. They obtain quite a considerable portion of their food from the excavations which they make for the deposition of their eggs, and as they show a strong inclination to oviposit only in clean or previously uninfested squares, their wandering in search of such squares

[a] The term "weevil-day" is used for convenience to designate the product of the two factors; number of weevils multiplied by the number of days.

keeps their punctures scattered so long as plenty of clean squares can be found. When clean squares become scarce, the normal inclination can not be followed out, and the number of punctures made in one square will be greatly increased. Most of the special feeding punctures of females appear to be made either in the early morning or near sundown, the middle and warmest portion of the day being given mainly to egg deposition. The total amount of feeding done is really very large, as is shown by a few figures.

MALES AND FEMALES TOGETHER.

During the season of 1903 a large number of weevils was kept in the laboratory for special study, but as several weevils were confined in each cage, the work of the sexes can not be positively separated. A comparison of the results can best be made by means of a tabular arrangement of the figures.

TABLE VIII.—*Number of punctures per weevil per day.*

Characterization of lot.	Number of males.	Number of females.	Total.			Average.		
			Weevil days.	Feeding punctures.	Egg punctures.	Feeding punctures per weevil day.	Egg punctures per female day.	Period of observation.
								Days.
Hibernated weevils in laboratory	55	54	4,938	17,406	5,702	3.5+	2.3+	45.3+
Hibernated females in field cage		4	93	284	489	3.0+	5.3−	23.3−
Weevils of first generation in laboratory	31	27	3,258	16,487	3,565	5.0+	2.4−	56.2−
Females, first generation, in field cage		5	70	263	435	3.8−	6.2+	14.0
Males only, laboratory, summer of 1903	65		2,492	5,617		2.3−		38.3+
Total	151	90	10,851	40,057	10,191			

FEEDING OF HIBERNATED WEEVILS ON EARLY COTTON.

During the period in which hibernated weevils were coming from their winter quarters and seeking their first food, frequent examinations were made in fields where the cotton was most advanced to learn the first-food habits of such weevils. From statements made by previous investigators the writer is led to believe that the season of 1903 at Victoria was abnormal in respect to the small number of hibernated weevils which were to be found upon the young cotton in the field. The most careful search failed to discover more than a very few weevils, whereas at the same season in some years hibernated weevils have been picked in large numbers from the young cotton growing in the infested territory.

Whether they be few or many, however, makes no difference in the feeding habits of the hibernated beetles. The stage of the cotton determines largely the nature of the food habits at this time. Owing

to the extremely wet winter and the very late spring of 1903, little cotton could be planted until the latter part of March or the first part of April. In such a season as this, therefore, cotton must be small at the time of the emergence of the weevils from hibernation, and some time must elapse before the formation of the first squares furnishes the weevils with their normal food supply. During this interval the weevil gets most of its food from the tender, rapidly growing terminal portion of the young plants, as several observers have noted. The central bud, young leaves, or the tender stems are attacked and upon these the weevils easily subsist until squares are developed, after which they confine their injury to them.

The earliest plants in a field seem to attract most of the weevils, and where seppa[a] plants occur they serve as excellent traps to draw the first attacks. Thus, in the spring of 1895 Mr. E. A. Schwarz found the first emerged hibernated weevils working upon seppa plants which had sprung from 2-year-old roots. These plants seem to start earlier and grow more vigorously than do those from seed and are therefore doubly tempting to the hungry weevils.

In 1896 Mr. Marlatt noted "the eating in the field on volunteer cotton is practically confined to the young expanding leaves at the bud and to the tender petioles or stems of this portion of the plant."

In the spring of 1903, in one field of comparatively early cotton, 2 or 3 acres in extent, the writer found, between April 24 and May 11, 23 weevils working on the buds and tender leaves of seppa plants before a single weevil was found upon the young planted cotton having from 4 to 8 leaves.

If, however, the cotton should be further advanced at the time the weevils appear, they would then go at once to the squares. Even then they prefer to attack the most advanced plants, which have a number of nearly grown squares, rather than the smaller plants which are but just beginning to square. Seppa plants, where such exist, come in, therefore, for a large part of the first attack of the hibernated weevils. This fact is well shown by observations made by Mr. A. N. Caudell, of the Division of Entomology, at Victoria, at about the middle of June, 1902. In an examination of 100 seppa plants growing in a planted field he found that fully half of the squares upon those plants were then infested. The planted cotton was just beginning to form squares, and was but slightly injured at that time.

INCREASE IN LEAF AREA OF COTTON.

The advisability of making observations upon this point was suggested by the attempts made to poison hibernated weevils by spraying early cotton with an arsenical insecticide. As the weevils fed so

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[a] "Seppa" is the term used by the Mexican residents of South Texas to differentiate the cotton plants springing from the roots of the previous year from those strictly "volunteer," springing from accidentally scattered seeds.

exclusively in the most recently unfolded growing portions at the tips of the stems, it was evident that the rapidity of increase in the leaf area would at least indicate the frequency with which spraying would have to be repeated in order to keep in a poisoned condition the very limited portion upon which the weevils fed.

Although the observations were made after midsummer, the plants used were of the right size to indicate the points desired. Two series, each including five average plants, were selected.

The plants used in Series I had 8 leaves at the time of the first observation. Those used in Series II were older and averaged about 30 leaves each. The leaves borne upon the main stem were classed as primary and those from side branches as secondary leaves. Upon the date of each of the 5 observations made, the number of leaves in each class was ascertained, an average leaf in each class was quite accurately measured, and the total product of numbers and area thus found was considered as the approximate leaf area of the plant. The error has been reduced as much as possible by taking an average of the 5 plants in each series as representing a typical plant, and it is with these results that comparisons have been made.

TABLE IX.—*Estimated increase in leaf area of cotton, averages of five plants.*

Date of examination.	Primary leaves.			Secondary leaves.		
	Average number per plant.	Average area, plant.	Percentage of daily increase.	Average number per plant.	Average area, plant.	Percentage of daily increase.
1902.						
Series I:		*Sq. in.*			*Sq. in.*	
August 30	8.0	64.0		0.0		
September 13	8.6	136.8	8.0	8.0	41.2	
September 25	9.8	231.6	5.4	16.6	187.4	30.0
October 6	11.0	309.6	3.0	22.6	347.8	7.8
October 17	13.2	376.6	2.0	31.0	522.4	4.6
Series II:						
August 30	7.8	177.2		21.6	266.8	
September 13	8.4	229.2	2.0	24.8	341.4	2.0
September 25	9.8	241.6	.04	42.4	514.0	3.6
October 6	9.6	214.8	[a]−1.0	52.6	619.2	1.8
October 17	10.0	216.8		67.4	808.8	2.1

[a] Decrease of 1 per cent due to falling of old primary leaves.

Several facts are evident from an examination of this table. After the plant has acquired about eight primary leaves the formation of branches and of secondary leaves began, thereby multiplying the number of growing points. From this time on the greater part of the increase in leaf area took place in the secondary leaves. By far the most rapid period of leaf growth occurred at about the time when squares first began to form. In Series I the average total leaf area practically doubled every ten days through the seven weeks under observation. In Series II the plants were older to start with, and it required about forty days to double the leaf area.

Everyone now concedes that it is useless to attempt the spraying of full-grown cotton such as is represented in Series II. The extreme

rapidity of increase in the foliage area shown in the first part of Series I shows that spraying must be repeated every week or ten days if even one-half of the entire leaf area is to be kept poisoned. When in connection with the large per cent of daily increase we consider how much of that percentage is being unfolded at the very tip of the stem; that upon that limited tip area alone will the weevil feed before the formation of squares; that after the formation of squares it appears to be absolutely impossible to poison the weevil's food supply, and also that the irregular emergence of the weevils from hibernation may extend through several weeks, it at once becomes evident that spraying early cotton for hibernated weevils is almost as impracticable as the spraying of older cotton is now acknowledged to be.

EFFECTS OF FEEDING UPON SQUARES AND BOLLS.

From numerous large, open, feeding punctures a square becomes so severely injured that it flares very quickly, often within 24 hours. Males usually make the largest punctures, and always leave them open while they remain for a day or more working upon the same square. It has been often found that squares thus injured by a male will flare before the weevil leaves it. The time of flaring depends upon the degree of injury relative to the size of the square. Thus, small squares receiving only a single large feeding puncture in the evening are found widely flared in the morning. On the other hand, large squares which are within a few days of the time of their blooming may receive a number of punctures without showing any noticeable flaring. Frequently a square which has flared widely will be found later to have closed again and to have formed a distorted bloom (Pl. VI, fig. 30; Pl. VII, fig. 31), and occasionally such squares develop into normal bolls. In squares of medium size a single feeding puncture does not usually destroy the square. The destruction of a square by feeding results either from drying, decay, or a softened, pulpy condition of the interior which is the consequence of the weevil injury.

Bolls are quite largely fed upon after infestation has reached its height. Small and tender bolls are often thoroughly riddled by the numerous punctures (Pl. VII, fig. 32). Small bolls so severely injured fall within a short time. Larger bolls may receive more punctures without being so severely injured. A comparison of the external and internal effects in such cases is shown in Pl. VIII, figs. 34, 35. Abnormal woody growth takes the place of the normal development of the fiber, and a softening and decay of the seeds often accompanies this change. One or more locks may be destroyed while the remainder of the boll develops in perfect condition (Pl. VII, fig. 33; Pl. X, fig. 38).

After the bolls become about half grown the effects of feeding are less liable to cause the boll to fall (Pl. I, fig. 10). The puncture becomes closed by a free exudation of the sap and a subsequent woody growth,

which forms frequently an excrescence the size of half a pea upon the inner side of the carpel. An excrescence of this character usually results from an egg puncture, and often from feeding punctures.

DESTRUCTIVE POWER BY FEEDING.

A glance at the figures in Table VIII (p. 40) is sufficient to show the great destructive power of the Mexican cotton boll weevil. It may be seen that both in the field and in the laboratory the weevils of the first generation are more active in making punctures than are the hibernated weevils. These generations overlap too far to attribute this difference to the influence of a higher temperature alone, though this factor will account for a large part of it. A comparison of the figures for males alone with those for females alone or with those for males and females together shows that it is very conservative to say that males make less than half as many punctures as do females. By the habit of distributing their punctures among a greater number of squares the destructiveness of the females becomes at least five times as great as that of the males.

This great capacity for destruction has been one of the most evident points in the history of the spread of the weevil, and deeply impressed the entomologists who first studied the insect in Texas. In 1895 Mr. E. A. Schwarz, in writing of the work of the weevil at Beeville, said:

> Each individual specimen possesses an enormous destructive power and is able to destroy hundreds of squares, most of them by simply sticking its beak into them for feeding purposes.

SUSCEPTIBILITY OF VARIOUS COTTONS.

An excellent opportunity for observations upon this point was obtained upon the laboratory grounds at Victoria by growing within a small area plants of several varieties of American Upland, Sea Island, Egyptian (Mit Afifi), Peruvian, and Cuban cotton (*Algodon sylvestre*). The Peruvian cotton made a remarkably large growth, but put out no squares, so that it does not really enter into this comparison. The Mit Afifi seed was obtained through the courtesy of the Bureau of Plant Industry of this Department from a field grown the preceding season at San Antonio, Tex., in which circumstances led some observers to the opinion that the variety was, to a certain extent, immune. The observations at the laboratory were made by carefully examining the plants, looking into each square, and removing every weevil and infested square found. If there were any distasteful or resistant cotton among these, it would surely be found in this way; and if any variety were especially attractive to the weevils it would be equally apparent. Infested squares being removed, the accident of association or proximity would not determine the location of the weevils found, but all might be considered as having come to the cotton with equal opportunities to make their choice of food, and accord-

ingly their location has been considered as indicating such choice. The period of observation extends from June to November, except with the Cuban cotton, which was planted late and began to square during the latter part of August. For the purpose of this comparison, both the varieties and the several plots of the American cotton will be considered together, as no evidence of preference was found among them.

In making a comparison of the results three elements must be considered for each variety of cotton: First, the number of plants of each variety; second, the number of days during which each kind was under observation; third, the total number of weevils found on each class of cotton. The elements of numbers of plants and times of observation may be expressed by the product of those two factors forming a term which we may call "plant-days." The total number of weevils found upon any class of cotton divided by the number of "plant-days" will give the average number of weevils attracted by each plant for each day, and these numbers furnish a means of direct comparison and show at a glance the average relative attractiveness of each class of cotton. The following table presents these results in comparable form:

TABLE X.—*Relative attractiveness of various cottons.*

Class of cotton.	Number of plants.	Total.			Average.		Relative attractiveness.
		Plant days.	Weevils found.	Infested squares.	Weevils per plant per day.	Infested squares per weevil.	
American	62	4,920	287	3,507	0.058+	12.2+	1.0
Cuban	5	120	11	136	.092−	12.4−	1.6+
Sea Island	8	552	64	1,089	.116−	17.0+	2.0
Egyptian	8	808	207	2,013	.256+	9.7+	4.4+
Total of 3 non-American cottons	21	1,480	282	3,238	.191−	11.5−	3.3−

An examination of these figures shows that American Upland cotton is less subject to the attacks of the weevil than any of the others, and that Egyptian (Mit Afifi) is by far the most susceptible. The difference in degree is most plainly shown in the column of "relative attractiveness." It would certainly seem difficult to formulate a stronger argument for the cultivation of American cottons alone within the weevil-infested district than is presented by these figures. The weevils gathered so thickly upon the Egyptian cotton that the plants could not produce sufficient squares to keep ahead of the injury, and therefore the average number of infested squares for each weevil is only three-fourths as great with that variety as with less infested kinds, but the average injury to each square was greater than with any other.

The practical application of these observations may be emphasized

still further by the statement that in spite of the frequent and careful removal of weevils from these cottons during the entire season none of the non-American varieties made a single boll of good cotton, so great was the actual weevil injury to them, while American cotton with the same treatment developed a large number of bolls.

The results are still further sustained by observations upon larger areas of American and Egyptian cotton under field conditions in three localities in Texas, no weevils being removed from either kind. At Victoria, Tex., on August 26, 1903, an examination showed that 96 per cent of Egyptian squares were infested, while an average of 13 fields of American showed 75.5 per cent. At Calvert, Tex., on September 4, Egyptian showed 100 per cent infested, while the American varieties growing alongside showed 91 per cent. Similar results were found at San Antonio. Though growing in close proximity, the Egyptian produced no staple whatever, while the American gave better than an average yield in spite of the depredations of the weevil.

In accordance with these observations, it appears that in developing a variety of cotton which shall be less susceptible to weevil attack by far the most promising field for work lies among the American varieties, and of these the very early maturing kinds are most promising.

The question of choice of different varieties for food was tested in the laboratory by Dr. A. W. Morrill, by placing squares of two kinds of cotton, American and Egyptian, in alternate rows in a breeding cage (Pl. XII, fig. 48), so lettered and numbered that each square could be exactly located. Weevils were then placed so that they could take their choice of these squares, and observations from 8 a. m. to 6 p. m. were made upon the location and activity of the weevils. Though this experiment was repeated four times, no positive evidence was obtained to show that weevils had any choice as to which kind of squares they fed upon. Table XI presents a summary of these results.

TABLE XI.—*Breeding-cage observations upon weevil choice of American and Egyptian squares.*

Experiment.	Period of observation.	Number of observations.	Weevils used.	American squares. Total number.	American squares. Infested.	American squares. Feeding punctures.	American squares. Egg punctures.	Egyptian squares. Total number.	Egyptian squares. Infested.	Egyptian squares. Feeding punctures.	Egyptian squares. Egg punctures.
1	12 m. to 8 a. m.	8	10	16	12	15	5	16	5	12	3
2	11.45 a. m. to 9.45 a. m.	5	10	16	5	19	1	16	5	13	3
3	12 m. to 5 p. m. day after	5	10	16	7	25	2	16	9	27	2
4	11.45 a. m. to 9 a. m.	5	10	16	6	17	6	16	8	14	3
5	6 p. m. to 8 a. m.	1	18	4	2	7	0	4	2	10	0
	Total	24	58	68	32	83	14	68	29	76	11

In experiments 1 and 2 the American squares were attacked more extensively than were the Egyptian, while in experiments 3 and 5 greater injury was done to the Egyptian. In experiment 4 the smaller number of egg and feeding punctures made in the Egyptian squares is counterbalanced by the larger number of squares attacked. Although the totals from these five tests show slightly less injury to the Egyptian than to the American squares, it could hardly be expected that two arbitrarily chosen series, even if of the same variety, would show any closer agreement in the points of comparison made in this table than is therein shown by the American and Egyptian squares.

HAS THE WEEVIL ANY OTHER FOOD PLANT THAN COTTON?

The question of the possibility of boll weevils feeding upon some other plant than cotton is one of great importance. It is a well-known fact that insects which have few food plants usually confine their attacks to closely related plants belonging to the same botanical family, or even genus. Accordingly, most of the plants which have been tested especially are most closely related to cotton. Four species of Hibiscus (*H. esculentus*, *H. vesicarius*, *H. manihot*, *H. moscheutos*) were grown and an effort made to see whether weevils would feed upon either the leaves, buds, or seed pods. In no case, however, did they live on any of these for any considerable time, though they fed slightly upon some of the parts. Hibernated weevils starved in an average time of about 4 days with leaves of either okra or Sunset Hibiscus. The buds and seed pods were not formed at that time, so could not be tested. Weevils of the first generation, which had had no cotton for food, were placed upon Sunset Hibiscus, and these starved in an average of 3 or 4 days. First generation weevils, which had fed for a few days on squares, were placed upon leaves, buds, and seed pods of *Hibiscus vesicarius*. Though they fed a little, all starved in an average of about 5 days. A lot of first generation weevils, fed first for several days with squares, were given leaves, buds, and seed pods of okra. More feeding was done by this lot than by any other, all parts being slightly attacked. These weevils lived for an average of 7 days.

Numerous other plants, including sunflower (*Helianthus annuus*), bindweed (*Convolvulus repens*), the slender pigweed and the spiny pigweed (*Amaranthus hybridus* and *A. spinosus*), and western ragweed (*Ambrosia psilostachya*), and various other species of weeds and grasses which occur more or less frequently around cotton fields were tested, but in no case was feeding noticed except in the case of weevils supplied with pieces of the stem of sorghum, the stems of which were cut into short lengths and some of the pieces split lengthwise. Upon the exposed, juicy pith weevils fed considerably, but they did not puncture through the hard stem to obtain the juice. The sweet

sap found in the pith sustained weevils for some time in the laboratory, but where obliged to puncture the stem, as they would be in the field, they would never attack sorghum, except possibly freshly cut stubble. Among the many plants tried, therefore, none has been found to show any capacity for sustaining the lives of weevils in the field in the absence of cotton.

The question of the original food plant of the weevil has received considerable attention from this Division, the investigations made in Cuba being particularly thorough and conclusive. In that island some varieties of cotton grow wild and are perennial. After most careful search Mr. E. A. Schwarz wrote in the spring of 1903: "There is not the slightest doubt, in my opinion, that the original and only food plants of the weevil are the varieties of Gossypium and here in Cuba the variety known as kidney cotton." The investigations of the Division of Entomology have given special attention to the possibility of the boll weevil breeding on other plants than cotton. Throughout the investigations of Prof. C. H. T. Townsend in southern Texas and in Mexico and the careful studies made by Mr. Schwarz in Texas and in Cuba and the observations made by the writers in Texas every plant closely related to cotton has been most carefully watched, and the uniform failure to find the weevil upon any other plant makes it practically certain that cotton is its only food.

INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Many species of insects have been mistaken for the Mexican cotton boll weevil. Among them the two most commonly reported in Texas have been an acorn weevil (Pl. XIV, fig. 55) and a species commonly found upon bloodweed or ragweed. The chief reason for the prominence of these two species is not that they resemble the boll weevil more closely than do others, but rather that their habits bring them into closer proximity with cotton fields and their abundance has led to their more frequent discovery. The acorn weevil has in a number of cases been taken in lantern traps set in cotton fields, and the mistake in the proper identification of the species has given currency to the report that the boll weevils are attracted to lights, which, however, is never the case. There is no authentic record of a single boll weevil having been caught at any light. Only very rarely and under exceptional conditions will the acorn weevil feed at all upon cotton bolls.

Though the bloodweed weevil (Pl. XIV, fig. 54) has been taken from cotton plants, no evidence has been submitted showing that it was actually feeding thereon, and it is more likely that such specimens had merely strayed to the cotton from bloodweed growing near.

Another species of weevil, *Desmoris scapalis* (Pl. XIV, fig. 58), is much less common and therefore less frequently mistaken, but resembles the boll weevil in general appearance far more closely than does

FIG. 29.—SQUARES MUCH FED UPON, NATURAL SIZE. (ORIGINAL.)

FIG. 30.—DISTORTED BLOOM, CAUSED BY FEEDING UPON LARGE SQUARE, NATURAL SIZE. (ORIGINAL.)

FEEDING INJURIES ON BLOOMS AND BOLLS.

Fig. 31, Blooms distorted by feeding punctures, open but imperfect, two-thirds natural size; fig. 32, small boll riddled by feeding punctures, natural size; fig. 33, one lock of boll destroyed by feeding punctures, two-thirds natural size. (Original.)

either of the species previously mentioned. This insect has been found attacking white prickly poppy (*Argemone alba*) and tumble-weed (*Amaranthus græcizans*) in the spring, and probably breeds on *Prionopsis ciliata* Nutt and the broad-leaved gum plant (*Grindelia squarrosa*).

In general the food habits of any species are among its distinctive, specific characters, and as the structural differences are easily overlooked and difficult of appreciation by anyone unacquainted with the careful study of insects, a rather full, though by no means complete, list is here given of the species which have been reported to the Division of Entomology as having been confused with the boll weevil.[a] Many of the most common species will be found figured among the illustrations. The scientific names of the insects are given because they are definite and refer positively to a single species, whereas the common names are used so loosely that the same name may be applied to a number of species having possibly similar habits. The boll weevil is included in this list, and figures of the adult are given in the plates to facilitate comparison. In many cases no common name has yet been given to the species. Seven of the species mentioned attack living cotton and five species are found feeding only in decaying bolls. The occurrence of the remainder upon cotton is merely incidental.

Insects often mistaken for the boll weevil.

Scientific name.	Common name.	Usual food plant.	Plate figure.
WEEVILS.			
Anthonomus grandis Boh	Mexican cotton boll weevil	Cotton squares and bolls	XIV, 52, 53.
Anthonomus albopilosus Dietz			
Anthonomus prunicida	Plum gouger	Plums	XIV, 57.
Balaninus uniformis auct	Acorn weevil	Acorns	XIV, 55.
Centrinus penicellus Hbst		Beetle in flowers	XV, 61.
Centrinus picumnus Hbst		do	
Chalcodermus æneus Boh	Cowpea-pod weevil	Cowpea pods	XV, 63, 64.
Desmoris scapalis Lec		Broad-leaved gum plant	XIV, 58.
Desmoris constrictus Say			
Dorytomus mucidus Lec		Willow	
Lixus læsicollis Lec	Blood-weed weevil	Ragweed (*Ambrosia* spp)	XIV, 54.
Coccotorus scutellaris	Apple curculio	Apple	XIV, 56.
Baris striata Say	Striped Baris	Stems of ragweed	
Baris transversa Say	Transverse Baris	Roots of cocklebur	XV, 59, 60.
Anthribus cornutus Say	Horned stem borer	Cotton stems	
Aræcerus fasciculatus DeG	Coffee-bean weevil	Coffee beans and old cotton bolls.	XV, 62.
Epicærus imbricatus Say	Imbricated snout beetle	Omnivorous	XVI, 69.
Hylobius pales Hbst			
Rhynchites mexicanus Gyll	Mexican rose beetle	Beetles attack rose	
Tychius sordidus Lec		Common in cotton fields	
Ophryastes bituberosus Shp		Found on cotton	
Trichobaris mucorea Lec	Tobacco-stalk weevil	Tobacco stalks	

[a] In the preparation of this list we are under obligations for assistance to Mr. F. H. Chittenden, who has also furnished information in regard to the food habits of the species.

Insects often mistaken for the boll weevil—Continued.

Scientific name.	Common name.	Usual food plant.	Plate figure.
OTHER BEETLES.			
Monocrepidius vespertinus Fab.		Larva in grass roots	XVI, 70.
Notoxus monodon Fab.		Larva in ground	
Ataxia crypta Say	Cotton-stalk borer	Cotton stalks	XVI, 68.
Olibrus apicalis Mels.		Decaying bolls	
Carpophilus hemipterus Linn		Develops in decaying bolls	
Carpophilus dimidiatus Fab		do	
Epurœa æstiva Linn		do	
Cathartus gemellatus Duv	Grain beetle	do	
Tribolium ferrugineum Fab	Flour beetle	Attacks seed	
BUGS AND OTHER INSECTS.			
Homalodisca triquetra Fab	Sharpshooter	Cotton stalks	XVI, 65, 66.
Oncometopia undata Fab	Waved sharpshooter	do	
Dysdercus suturellus H-Sch	Cotton stainer	Cotton bolls	XVI, 67.

IS COTTON-SEED MEAL ATTRACTIVE?

LABORATORY OBSERVATIONS.

On account of the popular impression that cotton-seed meal will attract weevils it has been necessary to conduct a rather full series of experiments. To ascertain the possibility of using this substance as an attractant for the weevil in field work three series of laboratory tests were first made. The weevils used were obtained from the same source in all tests. The first series was designed to test the ability of the weevils to live upon cotton-seed meal alone as a food. The second series was intended to show whether the weevils would prefer the meal to cotton leaves as an indication of the possibility of attracting hibernated weevils before the formation of squares in the spring. The third series was planned to show whether the weevils would prefer the meal as a food when squares could be easily found. The cotton-seed meal used was obtained fresh from the oil mill and the experiments started during the latter part of November.

Weevils fed rather sparingly upon the meal in Series I. It did not seem to agree with them as a food and they showed no special inclination to feed upon it. Twenty-three of the 24 weevils confined upon meal alone died in from 2 to 13 days, showing an average length of life of slightly over 6 days. These weevils either starved to death rather than eat the cotton-seed meal or else they were not able to eat it. The dry and empty bodies of all dead weevils showed that death was caused by starvation and not by disease. Being entirely covered with the fine meal did not seem to have any bad effect upon them. As weevils without food or water showed an average length of life slightly over 6 days, agreeing exactly with the period in this test, it appears that cotton-seed meal is not only not a food for the weevil, but also that it is not capable of prolonging their lives to any appreciable extent.

In Series II 21 weevils were confined with fresh cotton leaves and cotton-seed meal as food. During the 297 "weevil-days" that this experiment was continued but one weevil died. The average period of the test for each weevil was 14 days. The weevils fed almost wholly upon leaves. Occasionally one would feed a little on the meal, but they certainly preferred the leaves, and the results show that leaves alone were responsible for the longer life of these weevils. The 20 survivors were placed in hibernation December 20, 1902, but all died before April 15, 1903.

In Series III freshly picked squares were placed with the meal to see which would attract the weevils. Fresh meal, as well as squares, was supplied at frequent intervals. During the 158 "weevil-days" that this test continued not one of the 10 weevils died. The average period of the test was almost 16 days, and after it the weevils were placed in hibernation, but all died before April 15, 1903. In only one instance was a weevil observed feeding upon the meal. From this test it was evident that cotton-seed meal has not the power to attract weevils from squares, even when the latter have been picked for several days.

In spite of the complete failure indicated by these results, a series of field tests was made during the late fall of 1902.

FIELD TESTS.

In order to settle this question finally, two series of field tests were made, one during the fall, when weevils were abundant but full-fed and cotton still standing, and the other during the early spring, with the view of attracting weevils as they came from hibernation before cotton began to square.

Fall of 1902.—Cotton-seed meal fresh from the mill was placed in 10 cheese-cloth bags, which were shaken so that the fine dust from the meal covered the outside of each bag. The bags were numbered and then tied to cotton plants in infested fields at about the middle of the plants. The bags were so distributed as to test fields in which the following conditions prevailed: One field entirely black from frost, one nearly black, one about half green, and one still entirely green. The number of weevils on the plant to which the bag was attached was noted each day to ascertain in a general way the number of weevils which would be very near the meal and able to reach it in the ordinary course of travel over the plant without having to fly to it. Weevils on adjacent plants would naturally come within the sphere of influence if such existed, but they were disregarded. After the failure of the meal to attract weevils in the field became apparent, weevils were caught and placed upon the bags to see if they would stay there.

Altogether 65 observations were made, covering a period from November 24 to December 16. The weather was generally cool, averaging

about 61° F., mean temperature, and cotton had ceased to grow. Counting each weevil found at each observation, only 5 were found upon the 10 bags of meal. Of these 5, 3 were hidden in the folds of the cloth for shelter and were not feeding. One weevil was counted twice and was the only one found that appeared to be feeding upon the meal. During this period a total of 163 weevils was found upon the top parts of the plants to which the bags were attached. This is considerably below the real number present, because in many instances this examination was not made, and doubtless weevils were overlooked even when examination was made.

At various times 27 weevils were placed directly upon the bags of meal and given every opportunity to show whether they would stay thereon if they accidentally found the meal. Only one of this number stayed upon the bag for 24 hours, and this one remained in the shelter of the cloth.

The unattractiveness of cotton-seed meal for the weevils seems absolutely proven so far as fall conditions are concerned.

Spring of 1903.—These tests were intended to show whether hibernated weevils would be attracted to the meal before squares were to be found in the field. Two series of experiments were planned, using four bags of meal in each. For the location of the first series a field was chosen which was known to have been badly infested with weevils up to December 18, 1902. This field was not replanted with cotton in 1903, nor was there another field in the vicinity, so that weevils coming from hibernation would find no possible food except the meal. A number of live hibernated weevils was taken from this field, so that there can be no doubt of the presence of many of them. The bags of meal were placed near apparently favorable hibernating places.

Fifty-five observations were made under these conditions, but not a weevil came to the bags of meal.

For the second series a field was selected in which occasional seppa cotton plants were found. The plants had been allowed to stand through the winter in this field, and hibernated weevils were quite abundant. The bags of meal were here attached to stakes driven beside seppa plants. More than 50 observations were made after weevils were known to be out of their winter quarters. Nine weevils were found upon the seppa cotton plants beside which the bags of meal were placed, but not a weevil was found on the meal.

Only one conclusion can be drawn from these experiments. Under no conditions will cotton-seed meal serve as a food for the weevils, and it shows no power whatever of attracting them.

THE POSSIBILITY OF BAITING WEEVILS WITH SWEETS.

ATTRACTIVENESS OF VARIOUS SWEETS.

On account of the considerable publicity given the theory that it might be possible to destroy the weevil by attracting it to sweetened poisons, a number of experiments were performed along this line.

In the course of this work Mr. G. H. Harris employed in the laboratory tests a large variety of sweets. White granulated sugar, two or three grades of brown sugar, two or three grades of molasses, and the best strained honey were among the sweets tried. The conditions were such as to lead the weevils to eat the sweets if they would ever do so. The only alternative offered them for food was a supply of rather old cotton leaves such as weevils never touch in the field. In spite of the unfavorable conditions for getting at the real choice of the weevils they showed little inclination to feed upon the sweets except in the case of honey, which seemed to attract them quite strongly. Many weevils fed upon the unattractive leaf tissue or upon the broken end of the petiole rather than upon the sweets.

The result of Mr. Harris's experiments with undiluted molasses applied to plants in the field as summed up in his own words was that "nothing indicated that the weevils were attracted by the odor of sweets." Honey was then tried, and this did attract a few weevils. Mr. Harris's general conclusion, based upon the results of his experiments, was that "while a high grade of sweets seemed to have more attraction than a cheaper grade, neither can be depended upon to attract the weevils for poisoning."

ATTRACTIVENESS OF SWEETS TO HIBERNATED WEEVILS IN LABORATORY.

The sweets used in these tests were of three kinds: High-grade molasses, common molasses, and light-brown sugar. The weevils were brought in from the field and left for one week without food or drink previous to the beginning of the tests on April 2, 1903. Three weevils were used with each kind of sweet, the latter being in their strongest form and the sugar in a saturated solution. The inclosing apparatus was formed by placing two bottles mouth to mouth with sufficient space for air, but not enough for the escape of the weevils between them. In the bottom of one bottle was placed the sweet and the second leaves of cotton in the bottom of the other. The weevils were then inclosed, and the cages thus formed were placed in a horizontal position in the dark to eliminate every possible influence of direction of light, relative elevation of food, etc. The food supplies were renewed occasionally, and the location of the weevils relative to the food in each cage was noted frequently. The weevils were counted at each observation. The results of these observations are briefly summarized in the following table:

TABLE XII.—*Attraction of various sweets vs. cotton, second leaves.*

Character of sweet.	Number of observations.	Number of weevils on cotton.	Number of weevils at sweets.
Best molasses, cage 1	20	25	1
Best molasses, cage 2	13	29	5
Common molasses, cage 3	18	42	4
Brown-sugar sirup, cage 4	21	48	8
Total	72	144	18

These figures become even more striking in consideration of the fact that the cotton leaves were often purposely left until they became moldy and decayed or dried and wholly unfit for food. It was at such times that most of the weevils sought the sweet in preference. Should we leave out of the account the weevils found at the molasses or sirup when the cotton was unfit for food, the number attracted there would be reduced fully one-half. In either case the fact remains that none of the sweets can be said to have attracted weevils from the cotton leaves.

INFLUENCE OF SWEETENED WATER UPON FEEDING OF WEEVILS ON COTTON PLANTS.

It is easy to demonstrate that weevils will in confinement feed upon sweet solutions. To prove that they will show the same attraction to it in the field is a far more difficult matter.

For the purpose of these experiments, cheap molasses was used, mixing 1 part of molasses with 25 parts of water, as is generally recommended in spraying formulæ. Three pairs of young plants which had not begun to square were then selected from those growing upon the laboratory grounds. The plants in each pair were of equal size, and both in healthy condition and standing closely enough together to be both covered by one cage. One plant of each pair was then dipped in the sweetened water, while the other was left in its natural condition. In each of the cages 10 weevils were then placed upon the ground and midway between the bases of the plants. The object of the test was to see which plant, the treated or untreated, would attract the larger number of weevils. During the first three days observations were made several times each day. Weevils found upon either plant were counted at each observation.

A summary of the observations made on the first day before the liquid had dried showed 15 weevils upon the sweetened plants and 16 on those not sweetened. These results were so remarkably even that no attraction or repulsion could be ascribed to the liquid before it dried.

During the ten days covered by the observations, however, 63 weevils were found upon the unsweetened plants and only 45 upon those sweetened. The weevils fed largely upon the petioles and somewhat upon the blades of the leaves and the main stems of the plants. No indication was observed of special feeding upon the "gloss" left by the drying of the sweetened water. In each cage the normal untreated plant was destroyed before the treated one. During the first half of the observations 52 weevils were found feeding upon the unsweetened plants and only 32 upon the sweetened. Only after every leaf on the untreated plants hung black and dead, while the sweetened plants were in much better condition, did more weevils attack the sweetened plants.

Not only did these tests show that molasses in solution has no attraction for the weevils, but also that the sticky coating left after the liquid has dried acts more as a positive repellant to them.

FIELD TESTS FOR HIBERNATED WEEVILS, USING PURE MOLASSES.

As a final experiment to settle the possible usefulness of molasses in the weevil fight, a large series of tests was undertaken in the field to see if the pure, undiluted molasses would not prove attractive to weevils as they came from hibernation. To insure a continuous supply of fresh molasses a test tube was nearly filled and then rather tightly plugged with a small stopper wound with cotton. The tube was then fastened in an inverted position to the top of a stake about 2 feet long, and as the molasses gradually oozed through the cotton it ran slowly down the stake, forming a streak of continuously fresh molasses a foot or more in length. The supply would thus last for several days and was then easily replenished. This apparatus, as shown in Pl. XII, fig. 45, was then placed beside a vigorous seppa cotton plant in the field at the season when the weevils were beginning to leave their winter quarters and seek food to break their long fast. Both high and low grades of molasses were employed in these tests, three tubes of each being used. Altogether 84 observations were made between April 24 and May 15, 1903, during which period most of the weevils emerged from hibernation.

The results again proved disappointing, for only a single weevil was ever found at the molasses. This individual sipped occasionally at the sweet, wandering up and down the tube in the intervals. It did not appear to be satisfied and did not remain long at or near the molasses, but flew away and was not found there again.

The failure of the molasses to attract was not due to the scarcity of weevils in the field. During the period of observation 23 weevils were found working upon seppa cotton very near the molasses tubes, and certainly within reach of its attractive influence, provided it had any. More weevils were also found in the same field, but at somewhat greater distances from the tubes.

During the warm days toward the close of the experiment many butterflies, mostly *Vanessa atalanta* and some *Anosia plexippus*, came to the tubes. A few specimens representing several species of beetles and many ants were also found.

None of the experiments made, either in the laboratory or in the field at Victoria, Tex., has shown that weevils are attracted in even the slightest degree to any grade of molasses, either in its undiluted or diluted form. No sugar solution has been found to possess any more attraction than does molasses. Honey appears to be an especially attractive sweet, but is too expensive for use in this manner.

Considering the facts that these experiments have been much more numerous and that they have covered a much broader range of con-

ditions than any previously performed, we must conclude that it yet remains to be shown that sweets of any kind have any value in the problem of controlling the boll weevil.

FEIGNING DEATH.

This interesting habit of the weevil is its first resort as a means of escape from its larger enemies. It has been the basis of many machines designed to jar them from the plants and to collect them in convenient receptacles. If jarred from the plant, the weevil falls to the ground, with its legs drawn up closely against the body and the antennæ retracted against the snout, which is brought inward toward the legs. The position is characteristic and can be more easily shown than described. See Pl. I, fig. 2. In this position it often remains motionless for some time. If further disturbed, so that it finds that its ruse has failed to conceal it, it will start up quickly, run a little way, and again fall over, feigning death. The color of the weevil so closely resembles that of the ground that it is quite difficult to find a fallen individual so long as it remains quiet. The habit is of great value in protection. If left undisturbed until it believes danger to be past, it recovers its footing and returns to the plant.

REPRODUCTION.

Under this general heading we present some of the most interesting observations which have been made upon the habits of the boll weevil. The relation of the sexes, the evident selection of clean squares for egg deposition, the great destructive power of the weevil, the rapidity of development, and the influence of varying temperatures upon its activity and development may also be classed as among the most important as well as most interesting observations.

METHOD OF MAKING FIELD OBSERVATIONS UPON WORK OF WEEVIL.

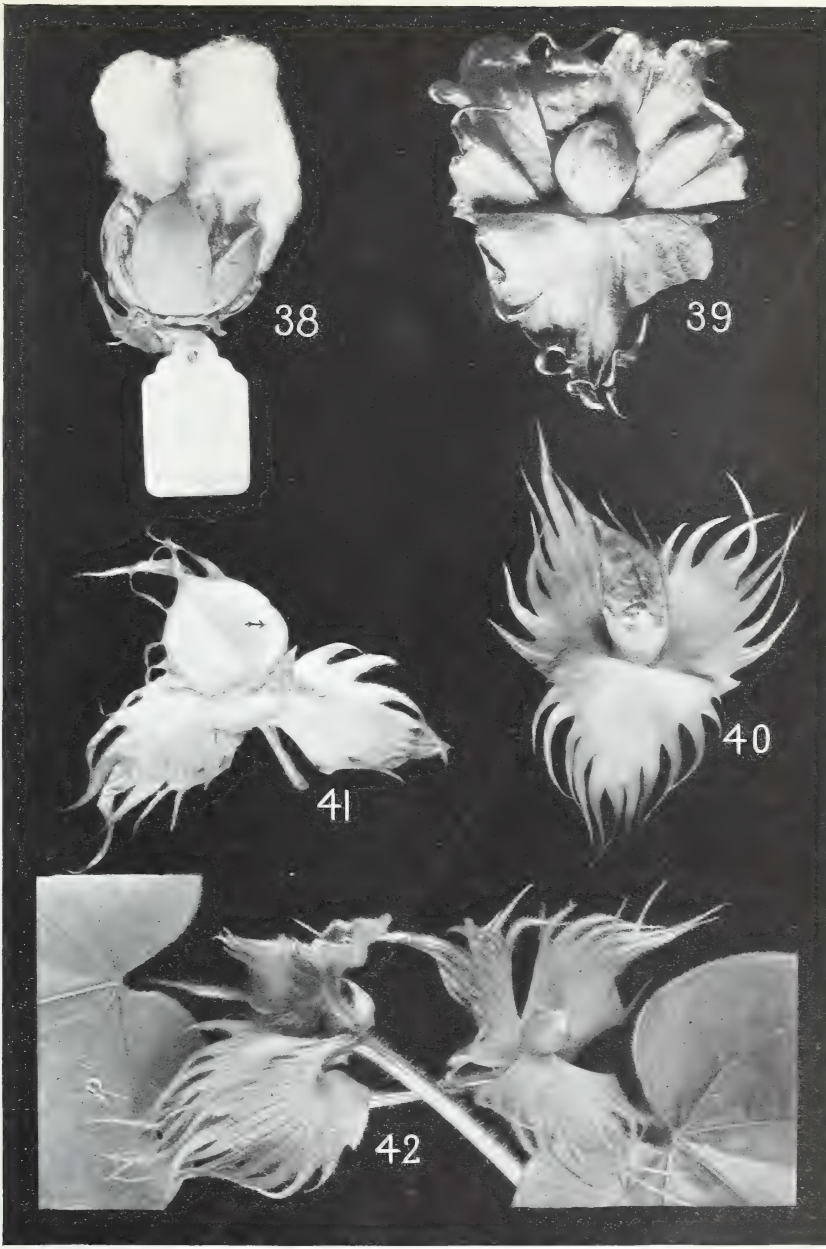
For the purpose of field study large cages (3 by 3 by 4 feet) were made, the covering being of fine wire screening (Pl. IX, fig. 36). Uninfested plants having plenty of squares were found by a careful examination of each square and inclosed by the cages. The number of weevils placed in each cage was varied according to the number of squares within, ranging from 2 to 5 at various times. In making the daily observations the cage was entered and each square examined. Each square found attacked in any way was marked with a numbered tag containing full data as to the lot of weevils and the number present, date, and nature of injury (Pl. IX, fig. 37). After all weevils had been found the cages were removed to new uninfested plants for another day's work. Close watch was kept upon all tagged squares upon succeeding days, and every important change taking place in each square was added to the record on the tag. The special points

EXTERNAL AND INTERNAL INJURY FROM FEEDING ON BOLLS.

Fig. 34, External appearance of large boll much fed upon, natural size; fig. 35, internal appearance of same boll, natural size. (Original.)

FIG. 36.—CAGES USED TO CONFINE WEEVILS IN FIELD. (ORIGINAL).

FIG. 37.—PLANT SHOWING TAGGED SQUARES FROM CAGE WORK. (ORIGINAL.)



EGG AND FEEDING PUNCTURES: EFFECTS ON SQUARES AND BOLLS.

Fig. 38, Boll showing two locks destroyed by two feeding punctures made by a male weevil, two-thirds natural size; fig. 39, square showing external appearance of two egg punctures, natural size; fig. 40, wart formed on side of square in healing an egg puncture, natural size; fig. 41, egg deposited on inside of carpel of a boll, two-thirds natural size; fig. 42, normal and flared squares, natural size. (Original.)

noted in each case, so far as was possible, were: The formation of a distinct wart; time of flaring, yellowing, and falling; the emergence of adult; presence of a parasite; death of larva, pupa, etc. A very complete history of each square was thus obtained. During the season of 1903 three special periods were selected for study of this kind. The first was taken during the early part of June, when hibernated weevils only were active, the second was taken in August for the work in midsummer, and the third in the latter part of October for the study of the development of late weevils. Altogether in these three series over a thousand squares were tagged and recorded. The work of males was compared with that of females in this way, as were also the developmental periods in squares and bolls. Although requiring a great deal of time and close attention, the numerous definite observations obtained abundantly justified the work required.

FERTILIZATION.

AGE OF BEGINNING COPULATION.

After the adult weevils have left the squares a certain period of feeding is necessary before they arrive at full sexual maturity. This period varies in length according to the effective temperature prevailing and appears to bear about the same ratio to the developmental period as does the pupal stage.

Among the many weevils kept from emergence till death for the purpose of ascertaining the length of life without food, copulation was never observed. With weevils fed upon leaves alone the period preceding copulation is about twice the normal length in the cases observed of those having squares to feed upon.

During the hot weather this period appears to be on the average only about three or four days in length, while as the weather becomes colder it increases gradually until weevils may become adult, feed for a time, and go into hibernation without having mated. A single union seems to insure the fertility of as many eggs as the average female will lay, and its potency certainly lasts for a period fully equal to the average length of life.

SEXUAL ATTRACTION AND DURATION OF COPULATION.

The distance through which the attraction of the female will influence the male varies extremely. To ascertain how far the attraction might be exerted in the case of the boll weevil, 2 females were confined with food in a small bottle covered with cheese cloth, and the bottle was then placed in a horizontal position inside a field cage and near its top. Within this cage were 3 males which had been confined there alone for 4 weeks. The bottle containing the females was so placed as to be within a few inches of the top of a cotton plant upon

which the males were working and touching the leaves of the plant, in order to afford the males access to the bottle without having to fly to it.

Close watch was kept, but during 11 days not a male was seen to go near the bottle. At the end of that time the females were taken into the laboratory, as was also one of the males from the cage. All were removed from squares and, being placed upon the table, were brought gradually nearer together. The male paid no attention whatever to the nearest female until brought within an inch of her. He then went directly to her. The sense of smell appeared to guide his movements. The fact that this male mated readily with both of the females used in the cage shows that the only reason for failure to attract in the cage lay in too great distance separating the sexes.

These observations are entirely borne out by those made in the field. The fact appears to be that the sexes are attracted only when they meet either on the stems or upon the squares of a plant. The comparative inactivity of the male has a bearing on this matter. The general conclusion is that instead of seeking widely for the females, the males are content to wait for them to come their way. The greater comparative activity of females is shown in the study of their food habits.

In a number of cases that were timed the average duration of the sexual act was very nearly thirty minutes.

DURATION OF FERTILITY IN ISOLATED FEMALES.

A number of females which were known to have mated were isolated to determine this point. Although neither limit was exactly determined, the results proved very striking. Several of these females laid over 225 eggs each and nearly all of them proved fertile. Selecting three cases in which the facts are positively known, it appears that fertility lasted for an average of something over 66 days and that during this period these females deposited an average of nearly 200 eggs. The maximum limits may possibly be considerably higher than these.

OVIPOSITION.

AGE OF BEGINNING OVIPOSITION.

Normal oviposition seems never to take place until after fertilization has been accomplished, but it usually begins soon after that. Observations upon the age at which the first eggs are deposited can be made more easily and more positively than those upon the age at which fertilization takes place. In a general way, therefore, the observations here given may be considered as also throwing light upon the time of beginning copulation.

In the breeding of weevils from eggs deposited by hibernated females a number of observations accumulated upon this point and another series was made in the fall of 1902. The results of both series are given in Table XIII.

TABLE XIII.—*Age of beginning oviposition.*

WEEVILS OF FIRST GENERATION, 1903.

Date adult.	Date of first egg.	Number of females.	Elapsed time.	Weevil days.
1903.	1903.		*Days.*	
June 8 to 9	June 17 to 18	3	9.0	27.0
June 10	June 19	1	9.0	9.0
June 11	June 16	7	5.0	35.0
June 12	do	1	4.0	4.0
Do	June 19	2	7.0	14.0
June 13	June 18	4	5.0	20.0
June 13 to 14	do	5	5.0	25.0
June 14	do	4	4.0	16.0
Total		27		150.0
Average time after adult				5.5+

WEEVILS BRED IN FALL OF 1902.

Date adult.	Date of first egg.	Number of females.	Elapsed time.	Weevil days.
1902.	1902.			
September 4 to 5	September 17	3	12.5	37.5
September 9	September 16	5	7.0	35.0
October 2	October 16	4	14.0	56.0
November 9 to 10	November 16 to 17	7	7.0	49.0
November 11	November 19	3	8.0	24.0
Total		22		201.5
Average time after adult				9.0+

The average time of 5.5 days, as shown by the first generation, is probably about a day and a half longer than the minimum average period during the hottest weather, while the 9-day average found from September 4 to November 11 is considerably short of the maximum average just before hibernation.

EXAMINATION OF SQUARES BEFORE OVIPOSITION.

In the course of a great many observations upon oviposition it was found that females almost invariably examine a square quite carefully before they will begin a puncture for egg deposition. This examination is conducted entirely by means of senses located in the antennæ and not at all by sight. In fact, the sense of sight appears to be of comparatively small use to the weevil.

In regard to the actual time spent in the work of examination before beginning a puncture 60 observations were recorded. These show that the average time is over two minutes.

This examination of squares is made by females only when they intend to oviposit. Males have never been observed acting in this way, nor do females generally do so when their only object is to feed.

SELECTION OF UNINFESTED SQUARES FOR OVIPOSITION.

So unerring is the sense by which examination is made that in a few cases it was able to discover an infested condition no external sign of which was visible to the writer's eye. A female which was under close observation examined the square given her in the usual manner, but though evidently searching for a place to oviposit and anxious to

do so, she plainly objected to placing an egg in that particular square. The writer again examined the square carefully, but found no sign of infestation and replaced it in the observation cage. Again the female made her usual careful examination and still she plainly refused to oviposit. Upon removing the covering from the square it was found to contain an egg, but the puncture made in depositing it had healed so smoothly that it had thrice escaped observation. The same female was then given two squares, one of which was known to be infested, the latter being placed nearer her. She examined it carefully, then left it, and went at once to the clean square, in which, after the usual examination, she deposited an egg.

The acuteness and accuracy of the preliminary examination is also well shown by the fact that when provided with more squares than they have eggs to deposit they rarely place more than one egg in a square. It was frequently found, however, that when a female deposited just as many eggs as there were squares present she would place two eggs in one and then make only feeding punctures in the remaining square.

The observations were made upon a large number of females; so there can be no doubt that the habit of selection is general. The conditions provided in these experiments were intended to resemble those existing in a slightly infested field early in the season, where each female could easily find an abundance of clean squares in which to deposit her eggs. Therefore only those cases were recorded in which the number of squares present equaled or exceeded the number of eggs deposited. Where a totally infested condition is reached no choice between infested and uninfested squares could be exercised, and then unless the female happened to be in a condition to refrain from oviposition she would be forced to deposit more than one egg in a square.

Not only do females show a strong inclination to place only one egg in each square, but they also object to making both egg and feeding punctures in the same square. That these conclusions are well grounded may best be shown by giving a summary of two long series of observations, the first made in the laboratory in the fall of 1902 and the other made in the field partly in the fall of 1902 and partly in the spring of 1903.

LABORATORY OBSERVATIONS.

Nine females were used in this series of experiments. The time followed varied with each individual, but ranged from October 23 to December 18, 1902. During this period a total of 868 uninfested squares was supplied to these 9 females. Of these squares 238 were not touched, while 630 were punctured, either for oviposition or for feeding or for both. The general results are here summarized in tabular form.

TABLE XIV.—*Selection of squares and relation of feeding to oviposition.*

No. of female.	Period of observation.	Squares supplied.	Squares with 1 egg each.	Squares with 2 eggs each.	Squares fed on only.	Squares with both eggs and feeding.	Squares untouched.
	1902.						
1	October 23 to November 15	135	72	2	25	1	35
2	October 23 to November 27	171	102	2	29	7	31
3	October 25 to November 7	96	74	4	8	1	9
4	October 23 to October 28	32	13	0	6	4	9
5	October 23 to October 28	38	30	1	2	2	3
6	November 10 to December 5	91	34	0	5	1	51
7	November 10 to November 25	75	41	3	7	1	23
8	November 10 to December 18	107	48	1	12	1	45
9	November 11 to December 12	123	63	6	16	6	32
	Total	868	477	19	110	24	238

A little calculation from these results shows that 82.5+ per cent of all squares attacked received eggs and that 91.7+ per cent of all squares oviposited in received only one egg each. The squares which were fed upon only formed 17.5− per cent of the total number attacked, and those receiving both egg and feeding punctures constitute only 3.8 per cent. The squares receiving two eggs each also form 3.8 per cent of all the squares which received eggs only.

The tendency to confine egg and feeding punctures to separate squares is strongly emphasized by the fact that in 17 instances, in which a total of 116 squares was provided, 91 received eggs only, while the remaining 25 were fed upon only; another total of 78 squares received 88 eggs in 72 of them, while the remaining 6 were fed upon only. As these two lots include nearly one-third of all the squares punctured, the tendency may be clearly seen.

FIELD OBSERVATIONS.

For one series of observations 500 infested squares were picked promiscuously in the field between May 28 and June 9, 1903.

A previous field examination was made about the middle of September, 1902, and this furnishes some very interesting comparisons as to the weevil's work upon the squares, especially at the beginning of the infestation and after it had reached its height. To facilitate an easy comparison, the results are arranged in Table XV.

TABLE XV.—*General results of observations upon selection of squares.*

	Total squares attacked.	Squares with 1 egg each.		Squares with more than 1 egg each.		Squares with both egg and feeding punctures.		Squares fed on only.	
		Number.	Percentage of all squares receiving eggs.	Number.	Percentage of all squares with eggs.	Number.	Percentage of total squares.	Number.	Percentage of total squares.
Squares infested in laboratory Oct. 23 to Dec. 2, 1902	630	477	91.7	19	3.8	24	3.8	110	17.5
Squares picked in field May 28 to June 9, 1903	500	317	79.25	83	20.75	50	10.0	110	20.0
Squares picked in field Sept. 17 to 22, 1902	105	56	62.9	33	37.1	46	43.8	16	15.2
Total	1,235	850		135		120		236	
Average percentage			84.2		13.4		9.7		18.3

A few obvious conclusions may well be stated here. Throughout the season from one-fifth to one-sixth of the squares injured were destroyed by feeding punctures alone. Within this small portion must be included most of the work of males and also of newly emerged females before they reach sexual maturity. As the weevil injury overtakes the production of squares it becomes increasingly difficult for females to find clean squares, and they are forced to deposit eggs in squares already injured and also to feed upon squares which already contain eggs. These conditions serve to increase most rapidly the proportion of squares containing both egg and feeding punctures. This is still further emphasized by the fact that in June only 30 per cent of all injured squares contained feeding punctures, while in September nearly 60 per cent had been thus injured. When females have access to an abundance of squares, they will deposit more than one egg only in about one-fifth of those in which they oviposit, while the proportion of those having both egg and feeding punctures is still smaller.

The tendencies to keep egg and feeding punctures separate, as well as to deposit only one egg in a square, serve to produce the greatest injury of which the weevils are capable for two obvious reasons: First, because where several eggs are placed in one square it is rarely the case that more than one larva develops. If two or more hatch in a square, one is likely to destroy the others when their feeding brings them together. They bite savagely at anything which irritates them, and larvæ have been found in the actual death struggle. Second, should eggs be placed in squares which already contained a partly grown larva, those hatching would likely find the quality of the food so poor that they would soon die without having made much growth. One egg will insure the destruction of the square, and a number of eggs, could all the larvæ live, would do no more. Therefore it is plain that the possible number of offspring of a single female is

increased directly in proportion to the number of her eggs that she places one in a square, and favorable food conditions for the larva are best maintained by avoiding feeding upon squares in which eggs have been deposited, and also by refraining from ovipositing in squares which have been much fed upon. These habits of selections are, therefore, of the greatest importance in the reproduction of the weevil, since they insure the most favorable conditions for the maturity of the largest possible number of offspring. In other words, these habits enable the weevil to do the greatest damage of which it is capable while the cotton crop is "making."

These habits are perhaps less strongly marked in the case of bolls, though still plainly manifested. Feeding and oviposition are common in the same boll, but unless the infestation is very great indeed it appears that only rarely is more than one egg placed in one lock, though several are often deposited in the same boll. The number deposited depends considerably upon the size of the boll. The smallest, which have just set, receive but one, as do the squares, and these fall and produce the adult weevil at about the same period as in the case of squares. Bolls which are larger when they become infested are often found to be thickly punctured and sometimes contain 6 or 8 larvæ. The weevil seems to know when the food supply is sufficient to support a number of larvæ and deposits eggs accordingly.

ACTIVITY OF WEEVILS IN DIFFERENT PARTS OF THE DAY.

The 5 females used in these tests were kept in a field cage on previously uninfested plants, and examinations of their work were made mostly at four-hour intervals from 6 a. m. to 6 p. m. The exact work found was recorded upon tags attached to the squares themselves. Temperature readings were taken at the same time as the observations. The results are most clearly presented in tabular form (p. 64).

TABLE XVI.—*Activity of five weevils in different parts of the day.*

Date.	Period.	Temperature.	Number of squares attacked.	Number of egg punctures.	Number of feeding punctures.	Condition of weevil at end of period.	Remarks.
1903.		° *F.*					
Sept. 2	2.30 to 6 p. m	93–80	16	15	10	Placed on fresh plant.	
Sept. 2–3	6 p. m. to 6 a. m	80–69	3	1	2	All resting	Punctures black at 6 a. m.
Sept. 3	6.15 to 10.15 a. m	69–85	12	10	2	All active	3 trying to escape; cage moved.
Do	10.40 a. m. to 2.40 p. m.	85–95	18	15	10	do	Cage moved.
Do	3 to 6.30 p. m	95–84	12	11	6	Placed on fresh plant.	
Sept. 3–4	6.30 p. m. to 6 a. m	84–68	3	1	3	All resting	Feeding punctures all black; small square flared.
Sept. 4	6.30 to 10 a. m	68–83	4	1	4	3 moving to adjacent squares.	
Do	10 a. m. to 4 p. m	83–91	24	19	12	All active	
Do	4 to 6 p. m	91–82	11	8	5	All quiet	
Sept. 4–5	6 p. m. to 9 a. m	82–79	5	0	6	All feeding	Cloudy; every weevil on same square as at 6 p. m.
	Total		108	81	60		

An examination of these figures shows that weevil activity began and ceased at about 75° F. Activity increased as the temperature rose, and its maximum coincided with the maximum of daily tem-

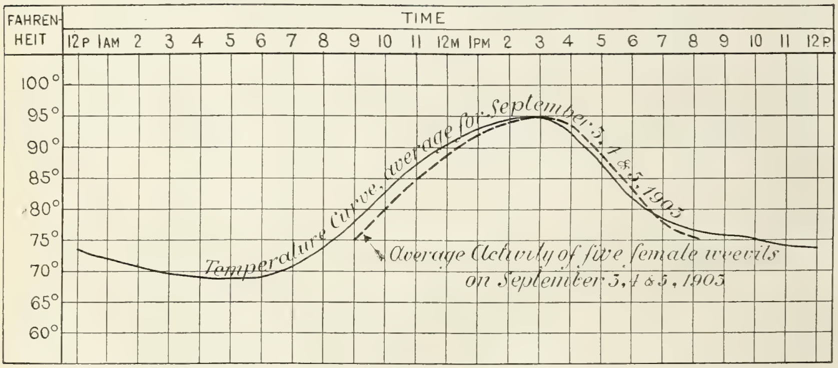


FIG. 3.—Diagram showing average activity of five female weevils. (Original.)

perature. It then decreased with the falling temperature until it ceased entirely some time during the evening, probably at about 75° F. See fig. 3. Feeding continued at lower temperatures than oviposition, as is known to be the case during the late fall.

Examinations made in the field between 6 and 7 a. m. on September 4 showed that all weevils, both males and females, were quietly resting at that time with the temperature at about 70° F. On cloudy days the activity is less than it is on clear days.

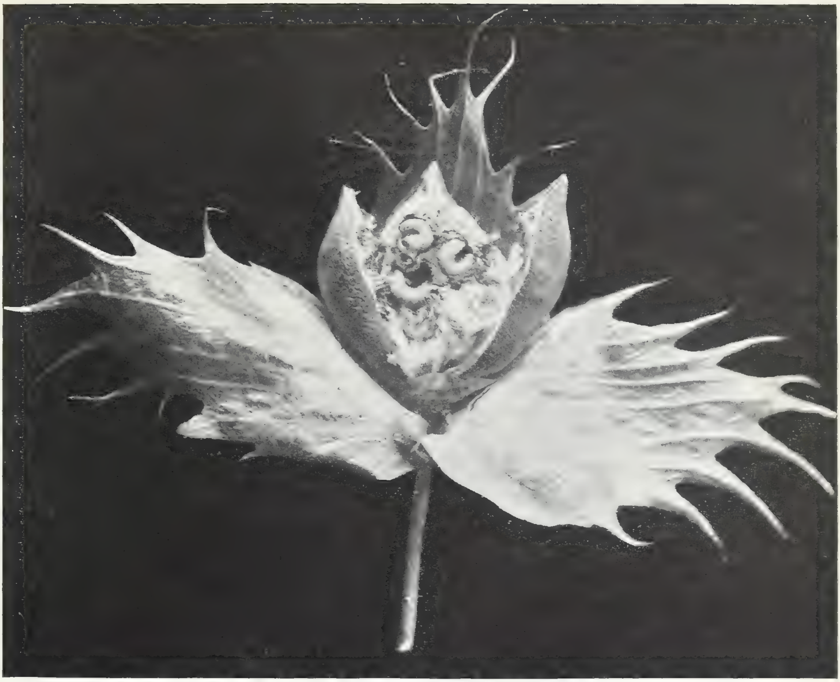


FIG. 43.—THREE LARGE LARVÆ IN A BOLL, TWO-THIRDS NATURAL SIZE. (ORIGINAL).

FIG. 44.—FOUR PUPAL CELLS FROM BOLLS (ON LEFT) COMPARED WITH FOUR COTTON SEEDS (ON RIGHT), NATURAL SIZE. (ORIGINAL.)

TESTING DEVICES. FALLEN AND HANGING INFESTED SQUARES.

Fig. 45, Device used to test attraction of molasses in the field in the spring; fig. 46, fallen squares on ground in field; fig. 47, infested squares dried and still hanging upon the plant; fig. 48, device used to test relative attractiveness to weevils of American and Egyptian squares. (Original.)

PLACE OF EGG DEPOSITION.

The location of egg punctures, while variable, still shows some selection on the part of the weevil. This may be due partly to the form of the squares and partly also to the size of the weevil, but whatever the explanation the fact remains that in a majority of cases the egg puncture is made on a line about halfway between the base and tip of the square. When so placed the egg comes to rest either just inside the base of a petal or among the lowest anthers in the square, according to the varying thickness of the floral coverings at that point (Pl. I, fig. 3). Punctures are very rarely made below this line, though they are sometimes made nearer the tip. Almost invariably the egg puncture is started through the calyx in preference to the more tender portion of the square, where the corolla only would need to be punctured. The reason for the choice of this location may be found under the subject of the "Relation of warts to oviposition," on page 69.

With bolls no selection of any particular location has been found, but eggs seem to be placed in almost any portion. Pl. X, fig. 41, shows the egg deposited inside the carpel.

POSITION OF THE WEEVIL WHILE PUNCTURING FOR OVIPOSITION.

While engaged in making egg punctures the favorite position of the weevil is with its body parallel to the long axis of the square and its head toward the base of the same. The tip of the weevil's body is thus brought near the apex of the medium size square. Having selected her location, the female takes a firm hold upon the sides of the square and completes her puncture while in this position. It may be that the position described is especially favorable for obtaining a firm and even hold, and this may have something to do with the regularity with which it is assumed. If so, the apparent choice of this location for the puncture is only partially explained, since it has been often shown that weevils can puncture and oviposit successfully in almost any portion of the square except its very tip.

Undoubtedly there are other reasons than those of mere convenience which have so impressed themselves upon the inherited experience of the weevils as to lead them to the choice of this position and the consequent location of the punctures and eggs. Most apparent of these reasons, and probably also most important, is the advantage which this location affords in the protection of the egg and the young larva developing from it against the attacks of natural enemies as well as from the injurious effects of drying and decay.

This protection is readily explained by several facts. The place chosen is through the thickest and toughest portion of the floral envelopes through which the anthers can be reached, since the thickest parts of both calyx and corolla are toward their bases. More

important than the thickness of the layers of vegetable matter is the character of the tissues through which the puncture passes. Though corolla and calyx are both modifications of original leaf tissue, both have changed so greatly in form and texture that the resemblance is recognized only by those somewhat acquainted with plant structure. The corolla, moreover, has changed far more than has the calyx, and in becoming so highly specialized its tissue has lost certain powers still retained by the green calyx tissue. The particular power referred to in this connection is the ability to heal small wounds. Punctures made in the corolla must, therefore, remain open, while small punctures through the calyx will in most cases be healed by the natural outgrowth of the tissue, so as to completely fill the wounds in a manner entirely analogous to the healing of wounds in the bark of a tree. The custom of the weevil of sealing up its egg punctures with a mixture of a mucous substance and excrement is of great advantage and assistance to the plant in the healing process. While undoubtedly applied primarily as a protection to the egg, it serves to keep the punctured tissues from drying and decay, and thus promotes the process of repair.

As a result of the growth thus stimulated in the calyx, the wound is perfectly healed in a short time, and, as is the case in the healing of the bark of trees, here also we find a corky outgrowth projecting above the general surface plane. This prominence the writer has termed a "wart" (Pl. X, fig. 40). The healing is completed even before the hatching of the egg takes place, and thus both egg and larva partake of the benefit of its protection.

It is possible for the puncture to heal without the full development of the wart, and it is also possible for eggs to develop successfully even when the puncture was made through the corolla alone and no wart developed, but in the latter case the chances are rather against it. Occasionally warts do develop from feeding punctures which were small, but the exact conditions under which this takes place have not been determined.

THE ACT OF OVIPOSITION.

The general process of making punctures has been described previously under the topic of "Food habits" (p. 38), and will therefore not be repeated here. Having completed the formation of the egg cavity, the female withdraws her proboscis and turns end for end. She depresses the tip of her abdomen and locates therewith the opening to the cavity by feeling or scraping around. In a majority of cases the opening is readily found, but sometimes it is not. Then the female seems often to lose all sense of locality, but continues scraping with the tip of her abdomen. If she is still unsuccessful, she turns and continues the search by means of the antennæ, just

as in the preliminary examination of a square before beginning a puncture.

In many cases females were noticed to actually place the tip of the proboscis within the opening of the cavity without seeming to be aware of its proximity. When the cavity has been found again by the antennal senses, the female invariably enlarges it before turning again to insert the ovipositor. If the search with the antennæ does not prove successful, the female will make another puncture in the same manner as at first, appearing to know that no egg has yet been placed in that square.

After locating the cavity by the tip of the abdomen, the ovipositor is first protruded to the bottom of the cavity, in which it appears to be firmly held in position by the two terminal papillæ and the power of enlarging the terminal portion of the ovipositor. Slight contractions of the abdomen occur while this insertion is being made. In a few moments much stronger contractions may be seen, and often a firmer hold is taken with the hind legs as the egg is passed from the body, and its movement may be seen as it is forced along within the ovipositor and down into the puncture. Only a few seconds are required to complete the deposition after the egg enters the opening to the cavity. The ovipositor is then withdrawn, and just as the tip of it leaves the cavity a quantity of mucilaginous material, usually mixed with some solid excrement, is forced into the opening and smeared around over the same by means of the tip of the abdomen. This seals the egg puncture and the act of oviposition becomes complete (Pl. X, fig. 39).

TIME REQUIRED TO DEPOSIT AN EGG.

Observations upon this point were very conveniently made by confining females upon squares from which the involucres had been removed. A plain glass cover allowed accurate observations, which were made to the fraction of a minute. The time required to complete the excavation and the time required to place the egg were the two points especially noted.

The time of making the puncture was noted in 115 instances, and this was found to average 5¼ minutes. The time varied widely, being from 1 to 13 minutes; the usual range was from 4 to 8 minutes. From the time that the weevil began to puncture till the sealing of the cavity the complete act of oviposition required in 103 instances an average of slightly over 7½ minutes, ranging in time from 3 to 16 minutes.

As these observations were made between October 7 and 23, the periods given may be slightly longer than they would be in warmer weather. However, various observations made in the field in midsummer agree very closely with the averages given.

RATE OF OVIPOSITION.

Since the period of reproductive activity of the boll weevil is so long, the rate at which eggs are deposited is a question requiring much time for its determination. There have been found great variations in the rate at different seasons, and it is clear that oviposition is even more strongly influenced by variations in temperature than is feeding. The rate sometimes varies unaccountably and very abruptly with the same female upon succeeding days. No explanation for this has as yet been found. The rate is influenced also by the abundance of clean squares which the weevil can find, so that it is greater in the early season, as the degree of infestation is approaching its limit, than after infestation has reached its maximum.

Two extended series of observations have been made to determine especially the normal average and the maximum ability of the female.

AVERAGE.

Taking first 54 females which had gone through hibernation, we find that they deposited on the average $2\frac{1}{3}$ eggs each daily in the laboratory, and 4 females which were followed under field conditions for a total of 93 "weevil-days" deposited 489 eggs during that time, or at the rate of $5\frac{1}{4}$ eggs each per day. Where the rate of activity is so great it is probable that the length of the period would be somewhat, but not proportionately, shortened. From many observations made in the field during the beginning of the squaring season it seems probable that a rate of 5 eggs a day is not far from the average in the field.

From 27 females of the first generation a laboratory average rate of $2\frac{1}{3}$ eggs each daily was obtained. Five females of this generation confined in a cage in the field during the latter part of August for a total of 70 "weevil days" deposited an average of $6\frac{1}{5}$ eggs per day. This latter rate is far beyond the actual average rate in the field at that period because of the fact that the weevils can not at that time find enough uninfested squares to lead them to deposit so many eggs, but the possibility remains if only squares enough are present.

A few words must be said in further explanation of the differences which appear between the field and laboratory results. In the case of the laboratory figures the entire oviposition period of each weevil and the entire number of eggs deposited are taken into the account. As there is a gradual increase in the rate of production of eggs after the beginning of deposition and a gradual decrease from the middle of the period to its end, the general average is much lower than would be that taken at the time of maximum activity. In the case of the field figures a short period only is covered, and all conditions of square supply were such as to stimulate the weevil to its greatest possible activity.

MAXIMUM.

The daily observations made upon the weevils in the laboratory supply a vast number of observations from which to select maximum figures. It has been shown that under favorable conditions weevils may be expected to produce an average of 6 eggs a day for a considerable period of time. It is not surprising, therefore, that some of the maximum figures obtained are very much larger than that number. A few instances only will be taken from among thousands of daily records.

The highest record of eggs deposited shows that 2 small females deposited together 108 eggs in 3 days, or at the daily rate of 18 eggs each. This record was made on the 7th, 8th, and 9th of June, 1903.

Table XVII.—*Maximum rate of oviposition.*

Number of females.	Days included in period.	Total eggs deposited.	Average per day.	Number of females.	Days included in period.	Total eggs deposited.	Average per day.
2	3	108	18.0	2	2	43	10.8
1	5	76	15.2	1	3	30	10.0
2	5	160	16.0	2	5	114	11.4
5	1	55	11.0	3	2	54	9.0
2	2	47	11.8	5	1	42	8.4
12	16	446	13.5	13	13	283	9.5

STIMULATING EFFECT OF ABUNDANCE OF SQUARES UPON EGG DEPOSITION.

Four actively laying females were confined together upon a few squares from September 22 till October 14, 1902, and during this period they laid a total of 227 eggs, or an average of 2.37 eggs per weevil per day. For the next 13 days these same weevils were isolated and supplied with an abundance of squares. During this shorter period they laid 236 eggs, or 4.54 eggs per female daily.

Taking equal periods as near together as possible and using these same weevils, there were deposited in 13 days upon a few squares 144 eggs, or 2.74 eggs per female daily, while during the following 13 days, with an abundance of squares, they each deposited 4.54 eggs a day.

These figures are the more striking because the stimulation was plainly shown in spite of the general tendency to lay fewer eggs as the weevils grow older and as the average temperature becomes lower.

RELATION OF WARTS TO OVIPOSITION.

When the general relation of the warts to the formation of egg punctures was first recognized, an investigation was undertaken to determine, if possible, in what proportion of cases the warts could be traced directly to egg or feeding punctures. For this purpose a large number of squares, most of which had warts, was picked from plants

in the field and carefully examined in the laboratory. Notes were made especially upon the following points: The number of warts, the number of punctures obviously made for feeding only, the number of special egg punctures, and the numbers of eggs, larvæ, and pupæ found. Only those excrescences were counted as warts which showed a positive elevation, and, as was expected, many eggs were found which had not been deposited long enough for a wart to have formed. Out of the 105 squares examined, 26 showed no warts, while the remaining 79 squares had 92 warts. In tracing the connection of these 92 warts it was found that 77 at least, or almost 84 per cent of the total, resulted from egg punctures. The other 15 warts, or 16 per cent, were assigned to feeding punctures, though some of these may possibly have been egg punctures in which decay had concealed all trace of the eggs or small larvæ. One-half of the eggs found were in punctures closed by developed warts, and it is likely that most of the other half were of too recent deposition for warts to have formed. Three-fourths of the larvæ found in this lot were in punctures which had been overgrown by warts.

In another series of 35 older squares, 38 warts and 32 eggs, larvæ, and pupæ were found. This series also shows that at least 84 per cent of the warts resulted from egg punctures. The conclusion seems justified, therefore, that warts may be considered as the most conspicuous external indication of the presence of the weevil in some stage within the square.

It should be noted in connection with warts that feeding frequently, and oviposition more rarely, is followed by a peculiar gelatinization of the injured portion of the square. This condition spreads, and the change produces a considerable internal pressure, so that the square becomes distorted and bulges, especially at the place where the puncture was made. The bulging portion often resembles somewhat a wart formation, but its real nature is very different. In many cases the gelatinized condition appears to have caused the death of the young larvæ, either by the pressure or by the abnormal condition of the food supply. In a large number of cases, however, this condition undoubtedly results from what were feeding injuries only.

EFFECTS OF OVIPOSITION UPON SQUARES.

The method of recording the progress of injury to each square, as was done in the field cages, has furnished much data upon a number of important points. Among these the two of most importance are, in order of their occurrence, the flaring and the falling of the square.

FLARING.

The flaring of squares (Pl. X, fig. 42) is one of the most apparent signs of weevil presence, although by no means an invariable accompaniment, as it is usually thought to be. Squares flare in nearly as

large a proportion of cases from adult feeding injury alone as from larval injury within. Any injury severe enough to cause the falling of the square is as liable to cause flaring as is the larva of the weevil. Flaring results from an unhealthy condition, whatever may be the cause, and is frequently to be seen in squares which are about to be shed, though they have never been injured by any insect. However, flaring has come to be popularly associated with weevil injury, and must therefore be quite fully considered.

When resulting from weevil injury, flaring does not begin, as a rule, immediately after the injury, but only within from one to three days of the time when the square will be ready to fall. In especially severe cases of feeding injury, flaring often results in less than twenty-four hours. Occasionally the growth of the square overcomes the injury from feeding and the involucre, after having flared, again closes up and the square continues its normal development as though uninjured, and forms a perfect boll. More frequently the square gradually loses its healthy green, becoming a sickly yellow in color, and falls in a short time.

When injured by the feeding of a young larva as the direct result of successful oviposition, flaring has been found in an average of 139 cases to take place in almost exactly 7 days from the deposition of the egg. These observations cover the season from June to September, when the developmental period averages about 19 days. Fully one-third of the weevil's full development has, therefore, taken place before flaring results.

FALLING.

Squares which flare because of injury from larval feeding within always fall, except the small percentage which, though entirely cut off from all vital connection with the plant, still remain hanging thereon by a small strip of bark and gradually become dry and brown upon the plant. Falling is but the natural final consequence of injury or disease (Pl. XII, fig. 46). Whatever its cause, it is brought about in exactly the same way as the shedding of leaves by the plant in the fall, by the formation of an absciss layer of corky tissue cutting off the fibro-vascular bundles supplying nourishment to the square. The exact location of the cork area is to be seen at the scar left by every fallen square.

In 539 cases definitely noted between June and September, 1903, the average time from egg deposition to the falling of the square was 9.6 days. For this same period full development required an average of 19 days, so that falling occurred at the middle point in the weevil's development. From a comparison of the time of flaring with that of falling it is seen that the interval between these two points averages about 2.5 days. In late fall the time between oviposition and falling, as recorded in 21 cases, was found to be about 16 days.

PERIOD OF OVIPOSITION.

With the exception of hibernated weevils, it appears that oviposition begins with most females within a week after they begin to feed and continues uninterruptedly until shortly before death. While females frequently deposit their last eggs during the last day of their life, a period of a few days usually intervenes between the cessation of oviposition and death.

In the case of 52 hibernated females the actual period of oviposition averaged about 48 days, the maximum being fully 92 days.

In an average made with 21 females of the first generation the actual period was almost 75 days, the maximum period being 113 days.

The average period for the females of the first two generations appears to be longer than that for any other. In the third generation the average period for 11 females was 58 days, the maximum being 99 days, and in the fifth generation for 5 females the period averaged 48 days, with the maximum only 62.

The approach of cold weather cuts short the activity of the weevils, which become adult after the middle of August, thereby decreasing the length of their oviposition period. Weevils which pass through the winter actually live longest, but as it must take more or less vitality to pass through the long hibernation period their activity in the spring is thereby lessened.

The weighted, average period of oviposition of the 89 females here mentioned is 55.6 days.

DOES PARTHENOGENESIS OCCUR?

To test the possibility of weevils reproducing parthenogenetically, 12 individuals were isolated from the very beginning of their adult life. Each beetle was supplied daily with fresh, clean squares and careful watch was kept for eggs. The first noticeable point was that no eggs were found till the weevils were about twice as old as females usually are when they deposit their first eggs. After they began to oviposit, it was found that a very small proportion of the eggs were deposited in the usual manner within sealed cavities in the squares, but nearly all of them had been left on the surface, usually near to the opening to an empty egg puncture. This same habit was shown by a number of females, and so can not be ascribed to the possible physical weakness of the individuals tested. The number of eggs deposited was unusually small, and those few placed in sealed cavities failed to hatch. After somewhat more than a month had been passed in isolation, one pair was mated to see if any change in the manner of oviposition would result. The very next eggs deposited by this fertilized female were placed in the square and the cavity sealed up in the usual manner, showing that her infertile condition had been the cause of her abnormal manner of oviposition.

A much more extensive series of experiments along this line is desirable and will be made.

DEVELOPMENT.

PERCENTAGE OF WEEVILS DEVELOPED FROM INFESTED SQUARES.

During the season of 1902 part of the many squares gathered in infested fields for the breeding of weevils were followed to learn something of the percentage which produced normal adults. No examination was made for those not yielding a weevil. The decay of the square during the period from its falling to the maximum time that must be allowed for weevils to escape normally so obliterates any small amount of work by a larva that it is difficult even with examination to determine accurately the number of dead small larvæ.

Table XVIII.—*Percentage of weevils from infested squares.*

Locality.	Approximate date.	Number of squares.	Number of weevils.	Percentage of squares producing weevils.
	1902.			
Victoria, Tex	July to August	1,125	360	32.0
Guadalupe, Tex	August	387	108	28.0
	1903.			
Victoria, Tex	June	334	106	32.0
Do	June to August	873	355	41.0
Do	August to September	368	192	52.0
Total		3,087	1,121	36.3

It seems safe to conclude that throughout the season fully one-third of the squares which fall after receiving weevil injury may be expected to produce weevils.

DEVELOPMENT OF WEEVILS IN SQUARES WHICH NEVER FALL.

It is generally true that squares seriously injured by the weevil sooner or later fall to the ground. Some plants, however, shed the injured squares more readily than do others. It seems to be a matter of individual variation rather than a varietal character. Thus occasional plants retain a large proportion of their infested squares, which hang by the very tip of the base of the stem. Normally the squares are shed because of the formation of an absciss layer of corky tissue across their junction with the stem. In the case of the squares which remain hanging the formation of this layer seems to be incomplete, or else it becomes formed in an unusual plane, so that while the square is effectually cut off, it merely falls over and hangs by a bit of bark at its tip (Pl. XII, fig. 47). In this position it dries thoroughly and becomes of a dark-brown color. Plants showing 6 or 8 of these dried brown squares are quite common in infested fields. Although exposed to complete drying and the direct rays of the sun, the larvæ within are not all destroyed. This peculiarity reminds one strongly of the European *Anthonomus pomorum* the work of which in caus-

ing apple buds to hang dead upon the trees has caused the common name of "Brenner" to be applied to it.

At intervals during the summer of 1903 such dried squares and small dried bolls were picked for careful examination in the laboratory, the condition of 342 being recorded, with the following results:

Adults present 2, escaped 23; pupæ alive 29, dead 2; larvæ alive 85, dead 47; parasites present 44, escaped 6. Sixty-three squares which failed to show weevil work and 42 small dried bolls from which the corollas had fallen were probably destroyed largely by the feeding of the weevils. Taking the total number of squares and bolls examined as the basis of computation, it appears that 69.3 per cent of them showed weevils present in some stage. Of the immature stages, 30 per cent were dead, 14.6 per cent having been parasitized. It seems a conservative estimate therefore to say that fully one-third of these exposed dried squares may be expected to produce adults. Considering the exposed condition of such squares this seems to be a very high percentage.

The season of 1903 was not as hot at Victoria as was that of 1902, and the lower temperature prevailing may have favored the development of a larger proportion of the weevils in these squares than would normally emerge. The maximum temperature reached in 1902 was 104.3° F., while in 1903 the maximum was only 97.5° F. No examinations of this subject were made in 1902, and therefore no positive comparisons can be drawn. The observations made, however, certainly show that a complete drying of the square does not necessarily destroy the larva, and that a square may undergo far more exposure to direct sunshine than had been supposed possible without causing the death of the larva or pupa within.

LENGTH OF THE LIFE CYCLE.

This question has been studied carefully, both in the laboratory and in the field. Most of the observations made in 1902 were in the laboratory, while those of 1903 were in the field.

In the laboratory uninfested squares were exposed to active weevils for oviposition, and the supply of clean squares was renewed each day. The beginning of the cycle was thus known to within a few hours. The squares with eggs were carefully kept and the date of emergence of each adult was then noted. To the period thus found must be added the time intervening between the leaving of the square and the deposition of the first eggs. This gives the length of the life cycle. The material upon which these observations were made was necessarily other than that used in determining the length of the various stages. The period in bolls is far different from that in squares. The figures here given refer to squares.

TABLE XIX.—*Length of life cycle.*

Observations.		Time in period of development.		Average time.		Temperature.	
Period covered.	Number.	Range.	Average.	Adult to oviposition.	Length of cycle.	Average effective.	Total effective.
1902.		*Days.*	*Days.*	*Days.*	*Days.*	*°F.*	*°F.*
August 10 to September 30	96	10–18	13.4	5.0	18.4	41.0	754.4
September 16 to October 15	305	12–25	17.5	7.0	24.5	33.64	823.2
October 8 to November 16	66	14–23	20.2	9.0	29.2	29.5	864.4
1903.							
Field, first generation:							
June 4 to July 15	100	12–22	18.3	5.6	23.9	32.0	764.8
August 20 to September 28	180	13–26	19.0	5.0	24.0	33.1	794.4
Total	747	10–26					
Weighted average			17.8	6.2	24.0	34.1	818.4

These observations cover the season from June 4 to November 16. Reproduction undoubtedly begins somewhat earlier and continues later in the average season at Victoria, but any differences which might be found at the extremes would not materially affect the location of the mean in so large a series. The influence of varying temperature during the same period but in different seasons is clearly seen by a comparison of the figures for August 10 to September 30, 1902, with those for August 20 to September 28, 1903. The period for 1902 was exceptionally warm, as shown by the high average effective temperature, while in 1903 it was decidedly cooler, the difference averaging 8° F.; consequently the average length of the cycle was fully six days greater in 1903 than in 1902 at the same period.

Determinations of the length of the life cycle in bolls have been made in only a few instances. In 7 cases between August 15 and November 11, 1903, the average time required from the deposition of the egg to the escape of the adult from the opening boll was 61 days. The average effective temperature for the period was 31.7° F., and the average total effective temperature required for development in bolls was therefore 1,933.7° F., or nearly two and one-half times as much as in squares. Several larvæ often develop within a single boll (Pl. XI, fig. 43). They appear to remain in the larval stage until the boll becomes sufficiently mature or so severely injured as to begin to dry and crack open. When this condition of the boll is reached, pupation takes place, and by the time the spreading of the carpels is sufficient to permit the escape of the weevils they have become adult.

BROODS OR GENERATIONS.

The term "brood" can hardly be applied in its usual sense to the generations of the weevil, as was pointed out by Doctor Howard in the first circulars of the Division dealing with the problem. For several reasons no line of distinction can be drawn between the generations at any season of the year, not even between hibernated weevils

and the adults of the first generation. As has been shown, the average period of oviposition among hibernated females is in some cases fully 3 months, while it averages 48 days. The length of the full life cycle for the first generation, as shown in Table XIX, is 24 days, and as the time for the second generation would be slightly less, it is evident that the first eggs for the third generation will be deposited at the same time as those for the middle of the second generation, and also with the very last of the eggs deposited by hibernated females for the first generation. The great overlapping of generations thus produced prohibits the application of any of the common methods of ascertaining their limits. The complexity indicated for the first three generations becomes still further increased as the season advances, so that in October, for example, a weevil taken in the field might possibly belong to any one of six generations. Length of life and the period of reproductive activity are important factors in determining the average number of generations. Periods of greatest abundance can not be regarded as giving any reliable information upon this point, since the number of weevils developed soon comes to depend largely upon the supply of squares.

In the case of the boll weevil, therefore, the information upon the number of generations must be drawn from laboratory sources. Many of the hibernated weevils continue to deposit eggs until the middle of July, and some are active for fully a month longer. In 1903 the last eggs from hibernated weevils were deposited on August 27. In the course of breeding experiments made in 1902 it was found that many weevils which had become adult about the 1st of August would continue to deposit eggs until the latter part of November. Considering the longest-lived weevils and their last-laid eggs, therefore, it is easily possible for two generations to span the entire year. The weevils developing after the middle of November may go into hibernation, and from their last-deposited eggs produce weevils whose last offspring will be ready for successful hibernation again. This conclusion is based upon actual demonstration.

The maximum number of generations will be found by taking the first, instead of the last, deposited eggs in each case. Rather than lay the conclusions open to question by taking the figures found for occasional minimum length of the life cycle, we will take the 24-day period, which has been shown to be the average between June 4 and November 16. Without doubt hibernated females begin their reproductive activity in average seasons by May 1, and their descendants continue to develop normally until after November 15. Taking the dates mentioned, however, as the average season for the weevils, we find that eight generations, each having the average period of development, may usually be produced within the year.

In determining the average number of generations one-third the average period of oviposition should be added to the average life cycle

for each generation.[a] As it has been found that the average period of oviposition is about $5\frac{1}{2}$ days, we must allow 24 days for the development of the average adult and 18 more days for the female to deposit one-half her eggs. Forty-two days is therefore about the average length of a generation; and we may thus count on an average of about five generations between May 1 and December 1. In the northern part of the weevil territory, where the season is shorter and the prevailing temperature lower, probably only four generations would be developed.

There is no basis for the idea that there is a distinct hibernation brood. The activity of the adults and the development of the immature stages is gradually retarded by the decline in temperature until hibernation time arrives. Most of the weevils of the first two or three generations have probably died, or then do so, while most of the adults of later generations, having still considerable vitality, will go into hibernation. It is certain that every generation preceding may have some direct part in the production of weevils which shall hibernate. All weevils which are still strong and healthy when cold weather comes on may be expected to go into hibernation, so that there can be no special brood for this purpose.

THERMAL INFLUENCE UPON ACTIVITY AND DEVELOPMENT.

The influence of temperature has been frequently mentioned as an important point, but it may be more clearly understood by collecting some of the most important observations relating to it. A study of this subject throws much light upon such questions as seasonal and daily activity, the rapidity of development at various seasons, hibernation, and the time of emergence from hibernation. The influence upon development will be first considered.

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[a] One-third is nearer the correct fraction than one-half, since it has been found that weevils deposit considerably more than one-half of their eggs during the first half of their oviposition period.

TABLE XX.—*Thermal influence on development.*

Stage.	Number of observations.	Period.	Average time for stage.	Effective temperature.	
				Average.	Total.
		1902.	*Days.*	°*F.*	°*F.*
Egg	385	Sept. 4 to Oct. 3	3−	38.0	114.0
	107	Oct. 7 to Nov. 13	4+	30.0	120.0
	36	Nov. 24 to Dec. 15	11.0	19.0	209.0
Larva	195	Sept. 6 to Oct. 5	7.5	35.7	267.7
	15	Sept. 26 to Oct. 21	9.5	30.6	280.7
	15	Nov. 11 to Dec. 12	25.0	19.5	487.5
Pupa	161	July 6 to 31	3.5	39.65	138.8
	81	Sept. 15 to Oct. 3	5.2	36.0	187.2
	167	Sept. 24 to Oct. 28	6.0	31.1	186.6
	29	Nov. 2 to 13	7.6	26.2	199.1
	4	Dec. 2 to 29	14.5	18.5	268.2
Entire developmental period	96	Aug. 10 to Sept. 30	13.4	41.0	549.4
	305	Sept. 16 to Oct. 15	17.5	33.6	588.0
	66	Oct. 8 to Nov. 16	20.3	29.5	598.8
		1903.			
	100	June 4 to July 15	18.3	32.0	585.6
	185	Aug. 20 to Sept. 28	19.0	33.1	628.9

SUMMARY OF THE PRECEDING TABLE.

Stage.	Total observations.	Average period for stage.	Average effective temperature	Total effective temperature.
		Days.	°*F.*	°*F.*
Egg	528	3.75	35.1	141.6
Larva	225	8.8	34.3	301.8
Pupa	442	5.1	34.7	177.0
Total development	1,195	17.65	34.8	614.2
Observations on entire period	752	17.7	33.9	600.0

In studying the influence of temperature on development the figures upon the separate stages serve best, as they give the widest range. In each stage it may be seen that the maximum time is nearly, if not quite, four times the minimum, while the average effective temperature difference is in the inverse order, but about 2 to 1. In comparing the minimum and maximum total effective temperatures, it appears that when the average temperature is lowest the total heat required to complete the development of the stage is nearly twice as great as when the average temperature is highest. The length of the developmental period is therefore not exactly inversely proportional to the change in temperature. The retarding influence of decreasing temperature appears to affect each of the immature stages in very nearly the same degree. The total effective temperature required forms a specific constant, which is fairly uniform for average effective temperatures of between 30° and 40° F. These temperatures would, during most seasons, prevail from June to October, inclusive. As the average effective temperature falls below 25° F., however, there results a great and disproportionate retardation in the development. The reason for this difference may lie in the fact that when tempera-

ture is ascending from 32° F. it must attain a higher point to start weevils into activity than that at which the same weevil will cease activity when the mercury is going down.

The observations upon the length of the entire developmental period were made upon a different series of weevils. As is clearly shown in the summary given in the latter part of the table, the sum of the average lengths of the three stages agrees remarkably closely with the length of the entire period as found in the 752 cases observed. This close agreement, reached by entirely different methods, indicates that the series from which the averages are obtained are sufficiently large to give constant results, and therefore that the average period of development throughout the season of weevil activity is very close to 18 days.

This thermal influence upon activity in feeding and oviposition may be shown by taking various lots of weevils at intervals through the season. For this purpose the work of 10 males and 10 females has been selected, using the laboratory records for each lot. The time covered is 25 days in each case to secure a fair average, and 25-day intervals separate the lots from each other. The season thus covered begins with June 6 and ends with November 28, 1903. To make the comparison fair, average conditions as to sex, age, and individual activity must be established, and the records have been selected with these conditions in view.

TABLE XXI.—*Thermal influence on activity in feeding and ovipositing.*

Number of males.	Number of females.	Period.	Average effective temperature.	Total.		Daily average.		Average per weevil daily.	
				Feeding punctures.	Eggs.	Feeding punctures.	Eggs.	Feeding punctures.	Eggs.
		1903.	° *F.*						
10	10	June 6 to 30	32.1	2,189	794	87.6	31.8	4.4	3.2
10	10	July 25 to Aug. 19	36.5	2,325	1,061	93.0	42.4	4.7	4.2
10	10	Sept. 14 to Oct. 8	32.7	1,540	659	61.6	26.4	3.1	2.6
10	10	Nov. 3 to 27	24.6	900	217	36.0	8.7	1.8	0.9

The average number of daily feeding punctures is reckoned for both sexes alike. Though the females made more than half, the proportions can not be positively separated, and it would make no difference if we could do so. It is noticeable that the period of greatest activity comes in midsummer, with the first, second, and third generations actively at work. Hibernated weevils working in June show greater activity than do the mixed generations which occur together in September and October, though the temperature does not greatly vary. In November, with a marked fall in temperature, there is a corresponding decrease in work, but especially is this noticeable in egg deposition. It appears that at this season and later on the weevils are mostly eating to live until it becomes cold enough for them to hibernate.

LABORATORY EXPERIMENT IN EFFECT OF TEMPERATURE UPON LOCOMOTIVE ACTIVITY.

The experiments here given were performed by Dr. A. W. Morrill. In the absence of apparatus especially designed for such work, use was made of a very simple device, constructed as follows:

A thermometer was passed through a cork and inclosed in a test tube, which in turn was placed within a hydrometer cylinder of sufficient depth to inclose it (Pl. XIII, fig. 49).

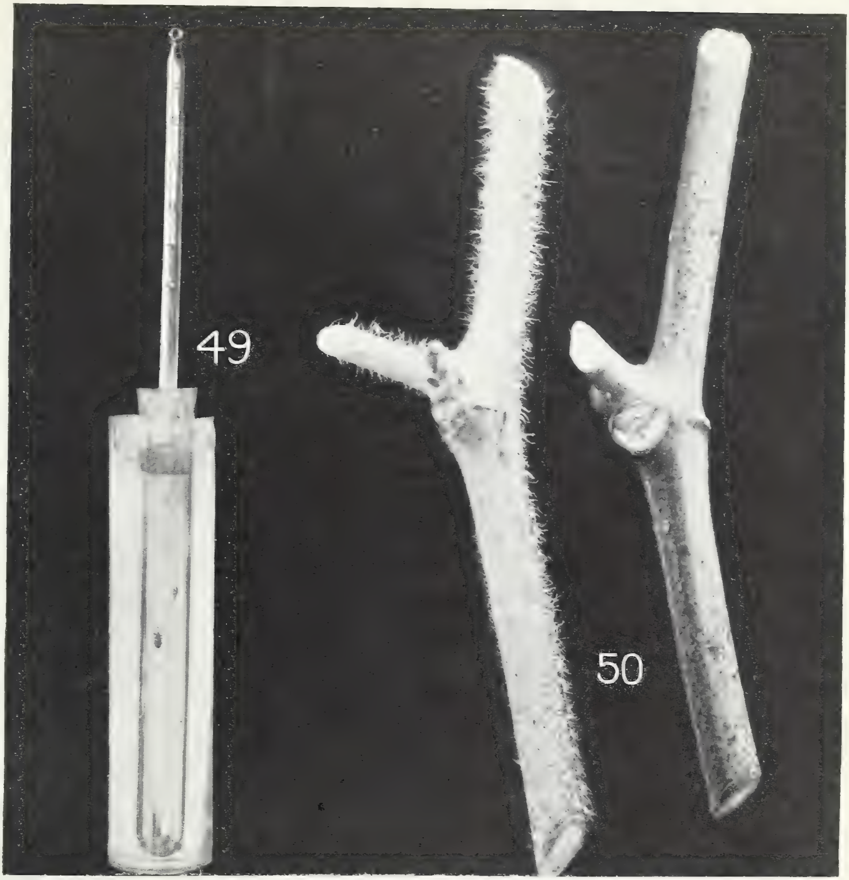
Weevils were inclosed in the test tube with the thermometer, and the temperature of the cylinder varied either by heating gently or by the use of ice water. Starting with the thermometer at 64° F., the 10 weevils inclosed were found to move slowly, half of them being quiet. As the temperature was gradually raised the activity of the weevils increased up to 105° F. When the temperature reached 95° F., or over, the weevils were running up and down the tube. By filling the cylinder with cold water the temperature was lowered to 86° F., at which point the weevils began to cluster at the top on the cork and were crawling slowly. By the addition of ice in the cylinder the temperature was lowered to 59° F., at which point 5 weevils were sprawling on the bottom of the test tube or clinging to one another, 4 were clustered on the stopper, while 1 was slowly crawling downward. At 50° F. 6 weevils at the bottom showed slight signs of life and 1 was crawling slowly. At 45.5° F. slight signs of life were still shown, while at 40° F. occasional movements only were noted. Upon the temperature being raised weevils began crawling as 50° F. was passed, and at 64° F. all had left the bottom and were crawling upward. Some recovered much more quickly than did others.

The temperature was again lowered, this time by the use of salt with ice. All movement ceased at 37° F. The cooling, however, was continued to 33° F., after which it was slowly raised to 42° F., at which point movements began.

In a general way these results agree quite closely with outdoor observations.

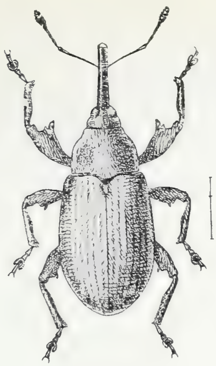
HIBERNATION.

Even after frosts have blackened the foliage and squares and entirely checked the growth of the plant, some weevils can be found moving in a cotton field upon warm days. Weevils which are old and nearly exhausted die as the cold weather comes on. Their vitality has been expended in other ways and they do not survive the winter. Those which are still vigorous and strong will continue to feed a little, and females will occasionally deposit eggs so long as cotton remains green. In southern Texas larvæ and pupæ which are in squares when frost comes are not killed thereby, but slowly finish their development if the weather is warm enough for any activity, and the young adults thus developed may live the winter through without feeding. As



FAVORABLE AND UNFAVORABLE CONDITIONS FOR WEEVIL ACTIVITY.

Fig. 49, Device used to test effect of temperature upon weevil activity, one-third natural size; fig. 50, comparison of pilosity on "King" (at left) and "Mit Afifi" (at right) stems, natural size; fig. 51, locality found very favorable to hibernation of many weevils. (Original.)



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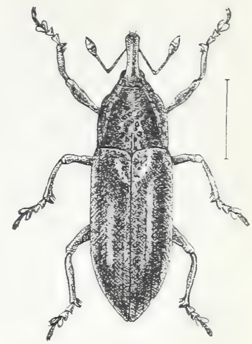

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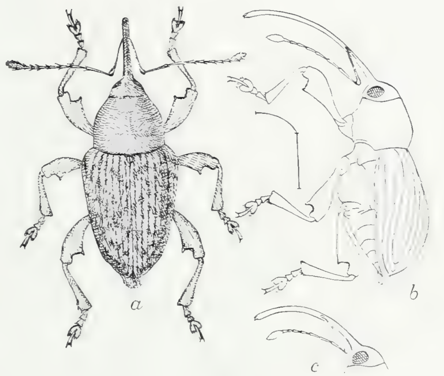

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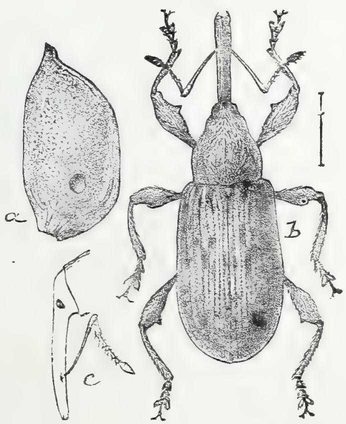

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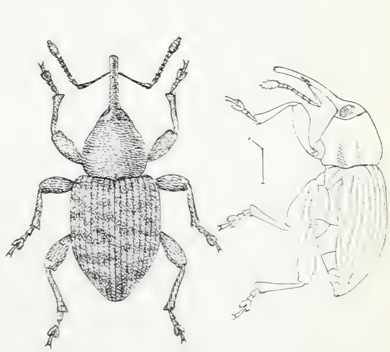

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INSECTS OFTEN MISTAKEN FOR BOLL WEEVIL.

Figs. 52, 53, Mexican cotton boll-weevil (*Anthonomus grandis*), much enlarged (redrawn, after Hunter); fig. 54, *Lixus* sp., enlarged 3½ times (original); fig. 55, acorn weevil (*Balaninus uniformis* auct.): *a*, female, dorsal view; *b*, same, lateral view; *c*, head, snout, and antenna of male—all enlarged 4 times (from Chittenden, unpublished); fig. 56, apple curculio (*Coccotorus scutellaris*), enlarged (from Insect Life); fig. 57, plum gouger (*Anthonomus prunicida*), enlarged (from Insect Life); fig. 58, *Desmoris scapalis*, enlarged (original).

observed by Mr. E. A. Schwarz in the winter of 1901–2, weevils may pass the winter in either larval, pupal, or adult stages, but the last named is by far the most common stage.

It is likely that a large part of the weevils found in the squares and bolls during the first part of the winter will be in the larval stage, while, owing to the slow development which takes place, a larger percentage of adults will be found toward spring. Mr. J. D. Mitchell, of Victoria, Tex., took a number of live larvæ, pupæ, and adults from bolls in a field in that locality on December 26, 1903, after "two hard frosts and one freeze." Two weeks later, from a field at the same locality, after three hard frosts and two freezes, he took another lot of live specimens in these three stages. In the latter case the bolls examined were on stalks which had been plowed out two weeks before and were ready for burning at the time examined. Mr. Mitchell, who is an excellent and reliable observer, writes: "On December 26, there was still some sap in the cotton stalks," and on January 10, when the second examination was made, "there was absolutely none." "The larvæ seem to thrive and arrive at perfection in the dead and dried bolls. A frost or freeze at 30° F. does not hurt the larvæ or pupæ in dead bolls in the field." As the two lots, taken together with four others sent January 17, 31, and February 7 and 14, 1904, include 197 specimens (23 larvæ, 30 pupæ, and 144 adults) it is evident that large numbers of weevils go into the winter in the immature stages, and there is every probability that, in the southern part of the State at least, many of them live and mature, emerging in the spring. It may be that this gradual maturity of the hibernated weevils is one of the reasons why they emerge so irregularly from their winter quarters. Not all weevils go into hibernation at the same time, but as the mean average temperature falls to between 55° and 60° F. they gradually cease feeding, and, numbed and sluggish, they crawl into almost any place which furnishes them some measure of protection from the cold. Hibernating weevils are therefore to be found in many situations in the field. Where the cotton stalks are allowed to stand throughout the winter they furnish the weevils both the means of subsistence late in the fall and an abundance of favorable hibernation places throughout the field. The prospects of successful hibernation are thereby multiplied many times; and, furthermore, the weevils are already distributed over the field when they first become active in the spring. The grass and weeds which almost invariably abound along fence lines are exceedingly favorable to the successful hibernation of many weevils, so that it will be found generally true that the worst line of infestation in the spring proceeds from the outer edges of the field inward. Where cotton and corn are grown in adjacent fields, or where, as is sometimes the case, the two are more or less mixed in the same field, many weevils find favorable shelter in the husks and stalks of the corn. An especially favored place is said to be in the

longitudinal groove in the stalk and within the shelter of the clasping base of the leaf. Perhaps the most favorable of all hibernating conditions are to be found among the leaves and rubbish abounding in the edges of timber adjoining cotton fields. From such places the weevils are known to come in large numbers in the spring. The timber fringes present greater difficulties in the way of removing the favorable conditions than do any of the other places mentioned.

Temperature and available food supply seem to be the most important factors in determining the time of hibernation. In general, it may be said that many weevils are active so long as their food continues in fit condition to sustain them. Some, however, undoubtedly seek shelter before frosts occur. From numerous observations made in the laboratory, it appears that weevils will starve when deprived of cotton if the mean average temperature continues long above a point somewhere between 60° and 65° F. As the mean average falls below 60° hibernation may take place successfully.

It is a very significant fact that of the 240 weevils taken from the field at the middle of December, 1902, and placed in hibernation, 38, or 15.8 per cent, passed the winter successfully, while of the 116 weevils adult before November 15, 1903, only 1, or less than 1 per cent, survived. It is evident that the weevils which pass the winter and attack the crop of the following season are among those developed latest in the fall and which, in consequence of that fact, have not exhausted their vitality by oviposition or any considerable length of active life.

LENGTH OF HIBERNATION PERIOD.

As the observations upon this point have all been made at Victoria, Tex., the statements made refer especially to that locality. It must be borne in mind that latitude and altitude, as well as seasonal variations, will influence the limits of this period. In general, however, it may be said that hibernation begins at about the time of the first hard frost, and that it continues until the mean average temperature has been for some time above 60° F. In the spring of 1903 weevils left hibernation quarters at Victoria only when the mean average temperature had been for some time at about 68° F. While it is true that weevils if disturbed in hibernation are active at much lower temperatures than this, for some reason they do not leave the shelter of their hibernation places.

At Victoria, Tex., the average hibernation season may be said to extend from about December 1 to about April 1, or a period of about 4 months. In more northern latitudes hibernation will, as a rule, begin earlier and last later, covering a period of from 4 to 5 months.

APPARENTLY FAVORABLE CONDITIONS FOR HIBERNATION.

In December, 1902, a series of experiments was started to test the influence of various conditions upon the successful hibernation of weevils. Owing to the writer's absence from Victoria examinations could not be made at intervals, as would have been desirable. But at the middle of April, 1903, careful examinations were made to ascertain the shelter in which live weevils were found. In the preparation of hibernation jars several inches of dirt was placed at the bottom, and above that a variety of such rubbish as was thought might tempt the weevils to shelter. Dead banana leaves, hay, cotton leaves, dry bolls, squares, etc., were among the things used as rubbish. As several of these were placed in each jar the weevils had an opportunity to choose their shelter. Among the 39 which lived through the winter, 19 were found in the banana leaves, 7 in hay, 5 in dry cotton leaves, 4 were buried in dirt, 3 were on the surface of the soil, and 1 was hiding in an open boll. It appears, therefore, that 31, or 80 per cent of the 39 live weevils, were found in what may be termed "leaf rubbish." It was noted also that 25 of the survivors passed the winter out of doors in various locations, while 13 were under shelter indoors. Of the weevils placed out of doors all but one lot were protected from the rain. The 15 weevils contained in the jar which became wet all died, while but few of the jars which were dry failed to show a live weevil in the spring. Leaf rubbish and dryness appear to be favorable factors in successful hibernation.

PERCENTAGE OF WEEVILS HIBERNATING SUCCESSFULLY.

Naturally the percentage of weevils living through the winter will depend largely upon favorable climatic conditions and the accessibility of suitable shelter. It would be utterly impossible to determine this question under actual outdoor conditions, and our inferences must be drawn solely from percentages found to survive under cage conditions. In the laboratory tests referred to in the preceding topic 356 weevils were used. Of these, 240 were brought from the fields at the middle of December, 1902. Among these weevils, 38, or 15.8 per cent, survived. The remaining 116 weevils were all adult after September 25, 1902, and had been kept under observation in the laboratory. One single weevil, adult November 12, was the sole survivor of this lot. Since the weevils brought from the fields in the middle of December would be a correct average of those entering hibernating conditions, we may disregard the laboratory specimens in drawing our conclusions. The conditions offered would seem to have been favorable, and when this is the case out of doors it appears that about one in six of weevils found in the field at hibernation time may pass the winter successfully. This seems a very high percentage, but when we consider the numbers of hibernating weevils often occurring

upon young cotton in the spring it seems not improbable that during favorable seasons something like this percentage of the weevils finding favorable shelter will live. Of course, the percentage finding favorable shelter will be extremely variable, and it is in reducing the number and accessibility of favorable locations that the cotton planter has one of his very best opportunities to effect the destruction of a multitude of weevils, and thus greatly reduce the number which will emerge from hibernation and attack the crop of the following season. With shelter removed, cold and changeable weather will inevitably destroy many, and, in fact, most, of the weevils which would otherwise survive.

SEASONAL HISTORY.

EMERGENCE FROM HIBERNATION.

Emergence depends largely, as has been already shown, upon the mean average temperature prevailing. The presence of food does not seem to affect it. In the season of 1903 for one month preceding the emergence of weevils at Victoria the mean average temperature was 65.4° F. For the first two weeks of April it averaged 68.4° F. Weevils left their winter quarters from the middle to the last of April. While the mean average temperature for May was nearly 3° lower than the temperature prevailing at the time of emergence, weevils remained actively at work in the fields. In the fall also weevils remained at work at a lower temperature than that which seems to be necessary to draw them from their winter quarters. The reason for this fact is not apparent, but it is certain that once having left hibernation weevils will remain active at considerably lower temperatures. If the temperature becomes too low they remain quiet without taking food for long periods of time. If taken from their winter quarters weevils will be found active at ordinary day temperatures long before they would normally venture from their hiding places of their own accord. Weevils thus removed have been kept for a month without food or water, and they then assumed their normal activities when food was supplied to them.

After considerable search at San Diego in the spring of 1895, on April 27 Mr. Schwarz found the first specimens working upon seppa plants from roots which were then 2 years old. As the weevils first appeared in that locality in August, 1894, the number of hibernating weevils could not have been as great as in succeeding years, and consequently in the spring of 1895 hibernated specimens were "exceedingly rare." At Victoria, Tex., in the spring of 1902, Mr. Schwarz found the first weevils working upon volunteer plants on April 15. In the same locality the writer found, in 1903, that weevils left their winter quarters between April 10 and May 1. Evidence was found indicating that in some fields they began to move as early as March 28. At Calvert, Tex., also in 1903, Mr. Harris found the first

weevils working on cotton on April 12. At Victoria, in 1904, weevils were found in numbers upon seppa plants on March 14 and they were found moving in the field at intervals throughout the winter.

From these observations it appears that normal emergence takes place usually some time in April, whether the first or the last of the month depending largely upon the earliness of the season. Furthermore, the emergence of the first weevils may take place from two to four weeks before that of the last. In this fact lies one of the two great obstacles which prevent the successful application of poisons to the early cotton as a means of destroying the weevils. The second obstacle is explained on pages 41–43.

Owing to the empty condition of the alimentary canal, hibernated weevils are able to fly with ease, and this they must do in their search for food. Doubtless many perish soon after emergence, even if they find food which many others never succeed in reaching.

APPARENT DEPENDENCE OF REPRODUCTION UPON FOOD OBTAINED FROM SQUARES.

During the fall of 1902 a series of experiments, lasting for 12 weeks, was made to determine the length of life of weevils fed solely upon leaves. In one lot, consisting of 9 males and 8 females, the average length of life of the females was 25 days, while that of the males was 36 days. Though this period far exceeded the normal time usually passed between the emergence of adults and the beginning of egg deposition, no eggs were found. Dissection of the females which lived longest showed that their ovaries were still in latent condition, though the weevils were then 81 days old. Few instances of copulation were observed among weevils fed upon leaves alone, and among nearly 70 weevils which were thus tested, no eggs were ever deposited. After a period of 3 weeks upon leaves, 11 weevils were transferred to squares. Females in this lot began to lay in 4 days, and 4 of them deposited 323 eggs in an average time of 20 days. The conclusion seems plain that so long as leaves alone are fed upon eggs do not develop, while a diet of squares leads to the development of eggs in about 4 days. It is worthy of note that the interval between the first feeding upon squares and the deposition of the first eggs is almost the same with these weevils taken in middle life as with weevils which have just emerged.

An examination of hibernated females taken in the spring of 1903, which had fed for 6 weeks upon cotton leaves, showed that their ovaries were still latent. Copulation was rarely observed among hibernated weevils until after squares had been given them. In a few days after feeding upon squares, mating and oviposition began. The average period was from 3 to 5 days, and having once begun, oviposition continued regularly.

It has been found that food passes the alimentary canal in less than

24 hours. Assimilation, therefore, must be very rapid. It is evident that while leaves will sustain life certain nutritive elements found only in squares are essential in the production of eggs.

Upon dissecting weevils just taken from hibernation it was found that females contained no developed eggs, but that their ovaries were in an inactive condition, similar to those of females which had fed for months entirely upon leaves during the previous fall. Upon examining females taken from seppa cotton later in the spring, but before squares had appeared, it was found that they also were in similar condition. This was also true of females kept in the laboratory from the time of emergence from hibernation until squares became abundant, with only leaves for food. It seems peculiar that upon a purely leaf diet eggs are not developed, but all observations made indicate that this is the case. It can not be said definitely whether the females examined had been fertilized, but it is certain that they were not ready to deposit eggs.

PROGRESS OF INFESTATION IN FIELDS.

From among the many notes made upon this point the results of the study of two fields are here presented. The first field, consisting of about 15 acres, had been planted in cotton for several years and was closely surrounded by other cotton fields. The second field of 35 acres was upon newly broken land and situated in a comparatively isolated location.

Examinations were made frequently to determine approximately the percentage of infested squares present in various parts of these fields. The conditions of the examinations were made as uniform as was possible. The fields were divided into blocks, and practically the same ground was covered in each block upon succeeding examinations.

TABLE XXII.—*Progress of infestation, field 1.*

Block.	Date.	Number of squares examined.	Number of squares infested.	Percentage.	Remarks.
	1903.				
I	June 8, 9	4,200	675	16.0	Work of hibernated weevils only.
I	July 13	467	211	45.0	Second generation at work.
I	July 22	249	193	77.5	Third generation beginning.
I	August 4	278	224	80.6	
I	August 29	91	85	93.5	About four generations now working.
II	July 30	358	168	46.6	Much cotton dying from root rot.
II	August 1	331	148	44.7	
II	August 4	300	100	33.3	
II	August 20	699	636	91.1	
	Total	6,973	2,440	35.0	

The observations made in Block I cover a longer period, and are, therefore, more suggestive than those made in Block II. Evidently infestation began with the first appearance of squares. So long as the hibernated weevils alone were at work the percentage did not increase very rapidly, but with the advent of the second generation

a much larger proportion of the squares became infested. Corresponding increases are seen with the third generation, but from that time on so large a proportion of the squares was infested that the percentage did not increase so rapidly. It may be noted in each block that the maximum percentage of infestation is slightly over 90. Some clean squares may always be found, however numerous the weevils may be, but those which escape weevil puncture are mostly less than half grown, so that while the percentage varies but slightly, few of these clean squares would escape the later attacks of the weevils and form blooms. In Block I the infestation was quite general. The situation of the block was especially favorable to the hibernation of a large number of weevils. Bounded on one side by a fence row, on the opposite side by a cornfield, and at one end by the buildings used by the tenant, an abundance of hibernating places was afforded the weevils, and as a result they came into the field in the spring from all those directions (Pl. XIII, fig. 51). It was noticeable, however, that the portion of greatest infestation early in the season lay in the corner between the fence row and the buildings. From the fence row especially the weevils spread toward the center of the field.

The second field, as has been stated, was comparatively isolated, so that infestation first began late in the season. Block I in this case lay in the corner between cross-roads. Block II adjoined the road farther on, while the third block was taken as far from these two as was possible. Infestation began in the corner covered by Block I. In studying this block, lots 1, 2, and 3, as numbered in the table, were taken diagonally across the block, away from the corner. Block II was separated from Block I by corn, the ends of the rows being at the road which passed the point of original infestation. The lots in Block II were taken in their order at varying distances from the road. Block III was some distance from the others. In this case lot 1 was taken along the edge on the side toward the other blocks, while lot 2 was taken in the middle of the block.

TABLE XXIII.—*Progress of infestation, field 2.*

Block.	Lot.	Date.	Number of squares examined.	Number of squares infested.	Percentage of infestation.	Remarks.
		1903.				
I	1	August 6	225	45	20.0	Infestation began in this corner.
		August 22	414	351	84.8	Lot 2, in middle of Block I.
	2	August 6	210	12	5.7	
	3	....do	200	0	0.0	Lot 3, opposite corner of block from lot 1.
		August 22	362	241	66.6	
II	1	August 13	185	62	33.5	Lot 1, near public road, passing lot 1 of Block I.
		August 24	180	156	86.7	
	2	August 13	202	31	15.3	
		August 24	136	105	77.2	
	3	August 13	150	9	6.0	
		August 24	200	130	65.0	
III	1	August 17	218	91	41.7	Edge of block.
		August 29	259	228	88.0	
		August 17	166	38	22.9	Middle of block.
		August 29	330	290	88.0	

From a study of Block I it is evident that infestation began some time in July, since when first found it was entirely restricted to a small area. A study of each block chronologically shows the steady but rapid progress of the weevil, as does also a comparison of the three blocks at the nearest possible dates. The tremendous activity of weevils in midsummer and the possible rapidity of their spread is clearly shown in this field.

A study of two other fields yielded practically similar results. The dates of examinations, with the percentages found in each case, will be given. In field 3 there was found, upon June 2, 3 per cent of infestation; on July 16, 25.9 per cent; on August 15, 65.9 per cent. This field was from native seed and was planted about three weeks earlier than field 4, which was of King seed, and just across a turn row from field 3. In field 4 infestation began very late, as on August 8 there appeared to be only 2 per cent and on August 15, 23.6 per cent, while on August 26 it had increased to 91.5 per cent, which is about the usual percentage of maximum infestation.

Under the conditions usually prevailing cotton will cease to make when about two-thirds of the squares have become infested, since the weevils have then become sufficiently numerous to attack nearly all of the remaining clean squares before they have time to bloom and form bolls. Even bolls which have set before this percentage of infestation is reached are not entirely safe, as the smallest ones will be more readily attacked by weevils, as they have greater difficulty in finding uninfested squares.

WEEVIL INJURY vs. SQUARE PRODUCTION.

At the beginning of infestation the indications of the weevil's presence are inconspicuous. Even when considerably advanced most farmers do not recognize the injury, and thus are led to believe that the insect has not appeared. Among the most conspicuous indications of the weevil's presence may be mentioned the falling of infested squares. As the squares remain on the plant after they become infested fully as long as they lie upon the ground between the time of their falling and the emergence of the weevil, it is plain that less than half of the actually infested squares will ordinarily be observed. Previous to falling infested squares gradually turn yellow, and in most cases flare somewhat; but flaring is by no means as closely related to weevil injury as might be supposed. As the percentage of infestation increases the great numbers of squares on the ground must attract attention (Pl. XII, fig. 46). Shedding of squares may take place for other reasons than the attack of the weevil, but in fair weather, when large numbers of squares are found upon the ground, the weevil is probably present. As infestation approaches its climax there is a great decrease in the number of blooms, and when a field is found at blooming age with many squares, but no blooms, the weevils are

almost certainly abundant. The conditions named form the most conspicuous indications of practically total infestation. During the season of 1903 it was found that a condition of total infestation was reached some time between August 1 and 20 in most fields within the infested area. This condition is, as a rule, coincident with the appearance in large numbers of weevils of the fourth generation. The exact time will vary in different seasons, and even in adjacent infested fields, because of varying conditions.

Not only is the maximum number of weevils present in the field in midsummer, but their capacity for injury is also greatest at that time. Practically all of the crop that will be made must have been set before this time. After this bolls will form only by accident.

A large series of examinations made by Messrs. Harris and Morrill at Calvert, Tex., shows the very rapid increase in the percentage of infested squares which usually takes place a few weeks earlier than it did in 1903. The figures given in each column in the table show also the closeness with which the weevil activity kept pace with the formation of squares after the period of maximum infestation had once been reached. The general influence of climatic conditions may be seen by a comparison of the last two columns in the table, but this point would be much more clearly shown by a series of examinations made during the first half of the growing season, at which time temperature and moisture would have greatest influence upon weevil development and injury. One hundred squares were picked promiscuously in each block for the determination of the percentages given in the columns for these 34 blocks, thus making a total of 17,000 squares examined.

TABLE XXIV.—*Study of the infestation of cotton fields at Calvert, Tex.*

Time of record.	Block.														
	1	2	3	4	5	6	7	8	9	10	11	12	20	21	22
1903.															
August 15–17	72	68	64	65	71	63	66	68	59	60	59	60	46	46	55
September 2–4	96	91	96	100	96	97	98	98	90	87	90	88	92	95	89
September 14–17	93	94	92	94	97	94	93	92	95	92	94	96	88	89	90
October 1–3	92	81	89	91	97	92	91	89	89	91	94	96	95	94	91
October 22–24	94	93	90	90	91	92	88	83	92	99	96	94	95	93	91

Time of record.	Block.														
	23	24	25	26	27	27 a	28	29	30	31	32	33	50	51	52
1903.															
August 15–17	48	50	54	47	49	52	54	58	54	54	57	55	62	66	58
September 2–4	69	94	91	91	88	93	95	91	91	93	93	97	89	94	96
September 14–17	92	91	92	94	93	92	90	96	94	96	93	94	93	92	95
October 1–3	94	94	90	96	93	94	92	92	95	99	94	96	92	87	86
October 22–24	95	91	89	98	94	91	97	90	97	95	97	93	96	97	97

Table XXIV.—*Study of the infestation of cotton fields at Calvert, Tex.*—Cont'd.

Time of record.	Block.				Average infestation for entire 34 blocks.	Climatic conditions.
	53	54	55	56		
					Per cent.	
August 15–17	64	69	67	62	58.88	Rainfall in July, 1903, 8.61 inches (or nearly four times normal rainfall); Aug. 1 to 15, nearly normal rainfall (0.79 inch, Aug. 2). Average temperature, July, 85° F.; Aug. 1 to 15, $85\frac{1}{4}$° F.
September 2–4	89	94	90	97	91.41	Rainfall from Aug. 15 to Sept. 2, 0.9 inch (nearly normal). Average temperature, same period, $84\frac{1}{2}$° F.
September 14–17	91	96	97	95	93.20	Rainfall from Sept. 2 to 14, 0.8 inch (about one-half normal). Average temperature, $83\frac{1}{2}$° F.
October 1–3,	78	92	88	89	91.56	Rainfall from Sept. 14 to Oct. 1, 0.14 inch (about one-tenth normal). Average temperature, $76\frac{2}{3}$° F.
October 22–24	95	99	98	95	93.67	Rainfall from Oct. 1 to 22, 3.63 inches (more than two times normal). Average temperature, 74° F.

Still another series of observations made by Doctor Morrill, at Austin, Tex., shows that similar conditions prevailed in localities nearly 100 miles apart. For each of these percentages 300 squares were examined, thus making 14,400 observations in the series.

Table XXV.—*Study of the infestation of cotton fields at Austin, Tex.*

Time of record.	Block.											
	1	2	3	4	5	6	7	8	9	10	11	12
1903.												
August 4–7	29.0	34.0	11.0	15.0	10.0	9.0	19.0	33.0	43.0	43.0	36.0	31.0
September 7–9	95.3	95.0	95.3	96.7	92.7	87.3	95.0	96.7	96.7	96.7	95.3	93.7
October 5–7	90.3	88.0	90.3	90.0	94.7	85.3	92.0	92.0	96.0	96.0	92.7	96.0

Time of record.	Block.				Average infestation, entire 16 blocks.	Climatic conditions.
	13	14	15	16		
1903.					*Per cent.*	
August 4–7	33.0	36.0	49.0	55.0	30.37	July rainfall, 12.65 inches (above normal 10.35 inches). Mean average temperature, July, 82.6° F.
September 7–9	93.7	98.0	98.3	97.7	95.25	August rainfall, 0.79 inch (below normal 1.64 inch). Mean average temperature, 82.6° F.
October 5–7	92.0	89.3	92.7	92.7	91.87	September rainfall, trace (below normal 3.72 inches). Mean average temperature, 76° F.

As the first records at Austin were made about ten days earlier than were those at Calvert, they serve to show a much greater total increase in the average infestation during August, though the average daily increase in the percentage of infestation agrees very closely in the two localities, being 1.8 per cent at Calvert and 1.9 per cent at Austin.

A decrease in square production accompanies the maturity of the bulk of the crop, owing to the fact that the assimilative power of the

plant is largely consumed in maturing seed. Dry weather normally occurring at this period also causes a decrease in the number of weevils present. Not only are there less squares to become infested, but each square is also subjected to greater injury, and many which would otherwise have produced weevils are unfitted as food for the larvæ by the decay which follows the numerous punctures. Several eggs may be deposited in one square, but as a rule only one weevil will result. At this season weevils turn their attention to young bolls upon which the injury previous to this time has been comparatively slight. It was found in one case that 35 or 40 per cent of the bolls were infested, while 15 per cent of the squares were yet clean. The longer period of development required by larvæ in bolls also serves to decrease the number of weevils produced. While the actual number of weevils begins to decrease within a short time after the period of maximum infestation is reached, the apparent numbers may possibly be greater. The decreased number of squares serves to concentrate the weevils upon those remaining, and therefore the number of weevils found in any square will be so much the greater.

RELATION OF WEEVILS TO "TOP CROP."

The hope of gathering a top crop is the "will-o'-the-wisp" of cotton planters. After considerable cotton has been matured fall rains often stimulate the production of a large number of squares, and many planters are misled by the hope of gathering a large top crop from this growth. The joints of the plant are short, and the squares are formed rapidly and near together. Though weevils may have been exceedingly numerous in the field, their numbers will have become so decreased in the manner described under the preceding heading that they can rarely keep up with the production of squares at this period of rapid growth. Many blooms may appear, and the hope of a large top crop increases.

The fact, however, as stated by prominent growers, is that before the appearance of the weevil they actually gathered only about three top crops in 25 years. The chance of its development, though always small, becomes hopeless wherever the weevil is present in considerable numbers. (See Tables XXIII, XXIV, and XXV, and average of infestation of entire fields, p. 88.) Neither the hopelessness of gathering a top crop nor the actual injury which is being done to the crop of the succeeding year by allowing that growth to continue until frost kills it is generally appreciated by planters. Because of the apparent abundance of squares and the presence of many blooms the plants are allowed to stand long after they might otherwise have been destroyed. As is the case in the early spring, however, the abundance of squares increases greatly the production of weevils; and though a few bolls may set, they are almost certain to become infested before they reach maturity. Every condition, therefore, contributes

to the production of an immense number of weevils very late in the season and at just the right time for their successful hibernation. As the result of this, far greater injury is done to the crop of the following season, with a comparatively small gain in the yield of the present season. Furthermore, plants standing until frosts kill them are often allowed to stand throughout the remainder of the winter, and these furnish an abundance of favorable hibernating places for the weevils. The consequence of this practice is that so many weevils are carried through the winter alive that the yield of the next year will be much less than what it might have been but for the farmer's indulgence of the forlorn hope of a top crop.

From these considerations it seems plain that within the weevil territory all hope of a top crop must be given up and the destruction of the stalks be practiced as early in the fall as may be possible. This practice is one of the essential elements in the successful control of the weevil.

SOME REASONS FOR EARLY DESTRUCTION OF STALKS.

It is naturally impossible to fix any date for the destruction of stalks which would apply to all localities and under all conditions. The condition of the soil must be considered as well as that of the maturity of the crop. While the condition of the soil can not be changed, the time of the maturity of the crop is largely within the control of the planter, since by early planting of early maturing varieties nearly the entire yield may be matured before the usual time of picking of the first cotton from native seed. Whatever the qualifications which must be made, they do not decrease the general strength of the reasons which may be given for the early destruction of stalks. The principal reasons are three in number:

First, the absolute prevention of development of a multitude of weevils which would become adult within a few weeks of hibernation time. The destruction of the immature stages of weevils already present in infested squares is surely accomplished, while the further growth of squares which may become later infested is also prevented. This stops immediately the development of weevils which would normally hibernate successfully, and by decreasing the number of weevils which will emerge in the spring the chances of a good crop for the following season are greatly increased.

The second reason is that by a proper manipulation of the stalks a very great majority of the weevils which are already adult can be destroyed. One of the most successful practices is to throw the stalks in windrows, and as soon as they have become sufficiently dry they may be burned. If the weather is favorable, the burning may take place in about two weeks, and many of the weevils will not have left the cotton stalks by that time. In case rains delay the drying it will be found advantageous to expedite burning by the use of crude petro-

leum. Grazing the fields with cattle, as some have recommended, will destroy much of the growth and prevent further development of weevils, but it allows enough of foliage to remain to sustain the life of many which are already adult until it becomes sufficiently cold for them to hibernate. Not only does burning destroy most of the weevils, but it also destroys the shelter which might be afforded the few that would escape, and the chances of successful hibernation are largely decreased by this practice.

The third reason may be found in the fact that the clearing of the ground renders possible a deep fall plowing. This catches such weevils as might still be in squares on the ground. The ground becomes clean by this practice, so that no vestige of the food plant remains, and living weevils, if by any possibility they have escaped thus far, must either starve or perish from exposure. Furthermore, fall plowing places the ground in the best possible condition and makes it ready for immediate working as early as planting may begin in the spring, thereby saving delay in the starting of the crop. As stalks must be destroyed in some way before the field can be replanted, the practices here mentioned will not add greatly to the cost of destruction. Even if some cotton is present upon the stalks at the time of their destruction, this small item is hardly worthy of consideration in comparison with the greatly increased crop and the more early maturing and better quality of staple which may be obtained by the adoption of this recommendation.

Having studied carefully the methods of weevil control which have heretofore been recommended, the writers firmly believe that *the destruction of the stalks in the early fall is the most effective method known of actually reducing the numbers of the weevil.* Early destruction will cost but a small fraction of the expense necessary to the frequent picking up of the squares infested by hibernated weevils in the spring, and is far more thorough as a means of reducing the numbers of the weevil than is the practice of picking hibernated weevils from the young plants.

Early destruction of the stalks is essential to the greatest success of any system of controlling this pest. All other practices recommended—early planting of early maturing varieties, thorough cultivation, fertilization, etc. (see p. 112)—though very valuable in securing the crop, are perhaps of greatest value because they prepare the way for this early destruction which so reduces the actual number of weevils hibernating successfully that the other recommendations may yield their best results. Since the earliest investigations made by this Division upon the boll weevil, it has been recognized that this practice is of the first importance, and the experience of recent years has but added certainty to this conviction. Planters have, however, been slow to change their methods of cultivation, but enough have adopted the recommendation to prove its efficiency. It must not be thought

that the procuring of the *immediate crop* is the only desideratum. *Early and complete destruction of stalks is undoubtedly the most important single element insuring success for the subsequent year.*

DISSEMINATION.

Two principal periods of dissemination may be found during a season. The first is when the hibernated weevils leave their winter quarters and go in search of food. Having found food, the spread is mainly controlled by the limitation of the food supply. So long as an abundance of growing tips or of clean squares is near at hand weevils will not travel far, but when the condition of total infestation is reached the period of greatest dissemination is also attained.

In any given field dissemination takes place mainly by the short flights and crawling of the weevils. The search of the female for uninfested squares is the principal factor in their movement. Heavy winds seem to be of comparatively small importance, as weevils do not take flight readily at such times; but light, warm breezes, such as prevail throughout the coast country of Texas, undoubtedly tend to carry them in a general northerly direction, and the continuous equinoctial storms of the fall in Texas, occurring at the very time the pests are most active, have undoubtedly had a strong effect in the same direction.

The two principal lines of spread will be found along railways and water courses. Between localities separated by short distances, traffic along highways is probably the chief factor. The distance which a weevil may travel in flight has never been determined, but from a study of their habits of flight it would seem to be comparatively short. Floods and the motion of water along water courses frequently serve to distribute many weevils along the edge of high-water mark. As river valleys are largely devoted to cotton culture, this would seem to be no small factor in the transportation of the weevils.

Over longer distances the usual means of commercial traffic must be held responsible. Shipments of cotton, whether for ginning or in baled condition, are likely to carry many weevils. Shipments of seed for planting, coming from infested localities, are almost certain to carry weevils, and shipments of seed to oil mills may also assist in scattering them. The pests are often carried far outside of infested regions in the shipment of seed to northern oil mills. From the mills they are carried to the farms in the hulls or other by-products used for feeding cattle. Many of the isolated colonies in northern Texas originated in this manner.

WEEVILS IN SEED HOUSES AT GINNERIES.

Careful observations made by Mr. Schwarz at Victoria throughout the winter of 1901–2 revealed great numbers of weevils about the gins. They occurred especially in the seed houses, and the danger of the

transportation of the pests from one locality to another was most evident.

A casual examination of the dirt separators which are now in use in the more modern ginneries shows that immense numbers of weevils brought in from the fields are separated from the lint by these devices. Even where these separators are used, however, a short search in the seed house will show that many weevils pass through alive. A single hour's search in the seed house of a first-class ginnery, where dirt separators are in use, yielded seven boll weevils in perfect condition, and a number of other and much larger insects. In addition to these a number of fairly large spiders, most of which were in perfect condition, were also found. Numerous pupæ may pass through the gins unharmed in the cells formed by the larvæ. These cells are similar, both in size and shape, to the seed, and may often be mistaken therefor (Pl. XI., fig. 44). Distribution of weevils in seed is therefore easily possible, and uninfested localities should guard carefully against importing weevils in this way.

The most valuable suggestion for reducing the important effect that gins have in spreading the weevil is in the improvement of the cleaning devices referred to above, and in encouraging their more general use. A particular study of this matter will be made during the season of 1904.

NATURAL CONTROL.

Doubtless many factors are concerned in the natural control of the boll weevil. The most important ones are probably included among the following topics:

MECHANICAL CONTROL.

PILOSE OBSTACLES TO WEEVIL PROGRESS.

In testing the susceptibility of various cottons to weevil injury it was found that the variety of Egyptian cotton grown (Mit Afifi) was more severely injured than was any other. The next in order were Sea Island and Cuban tree cotton, while the American cottons, represented especially by King's Improved, were less severely injured than were any of the others. It may be noted that the three varieties first mentioned seem more closely related to each other than any of them do to the American. The reason for the evident choice of these cottons was carefully sought for, but the only difference which seemed worthy of consideration was found in the varying degree of pilosity upon the stems (Pl. XIII, fig. 50). It was found that Egyptian stems were almost perfectly smooth, while Sea Island and Cuban resembled it closely in that respect. Many American cottons, and King's Improved especially, are quite pilose, and it was often noted that upon these weevils showed some slight difficulty in moving about or in climbing the pilose stems of the plant. While this obstacle to weevil

activity may seem slight to account for the evident selection of the smoother varieties, no greater difference could be found. As is shown by Table XI, on page 46, the selection is not due to a difference in taste of the squares.

In order to test the resistance which varying degrees of pilosity might offer to weevil progress, a number of experiments were made with various stems or fruits. In climbing upon the stems of King plants weevils would catch the spines with the forefeet while pushing themselves upward by means of the tibial spurs of the hind legs placed against the epidermis and between the spines. It was evident that their progress was considerably hindered, and several attempts were often made before a firm foothold was secured.

Okra pods were next tried, as upon them the spines are very short and stiff. Weevils climbed these pods with little difficulty.

The seed pods of Sunset Hibiscus were also tested. The spines upon these are from 2 to 3 millimeters long; they stand thickly and are quite stiff. Over these spines weevils walked easily, but though they attempted vigorously to get their heads down between the spines far enough to feed, they were unable to do so. A number of weevils were kept for several days upon these pods, but they were unable to feed. The spines were then removed from a small area, and the insects began to feed immediately.

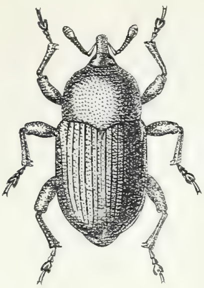
Weevils travel with difficulty over loose cotton fibers, as their feet become entangled among them.

DESTRUCTION OF LARVÆ AND PUPÆ IN BOLLS AND SQUARES BY ABNORMAL PLANT GROWTH.

In making examination of several thousands of infested squares a small percentage was found in which the larvæ had evidently been killed by an abnormal condition of the interior, which may be characterized as a process of gelatinization. This change begins at the point of injury and spreads. Instead of the normal growth of the anthers there takes place a change which appears to be something like the swelling of starch granules. The interior becomes soft and pulpy, and by the swelling considerable internal pressure is produced. The death of the larvæ results either from unfavorable food conditions or from the internal pressure, which in many cases is sufficient to distort the square. Whether from these or other causes, from 10 to 20 per cent of the larvæ usually die within the squares.

Gelatinization sometimes occurs in small bolls, but more rarely as bolls become larger and more mature. In large bolls in which seeds are nearly matured the feeding of the weevil larvæ often causes seeds to sprout, and in several such cases pupæ have been found crushed by the rapid growth of the caulicle.

In examining nearly 1,000 bolls, taken partly from King and partly from native cotton, it was found that in the early maturing King the



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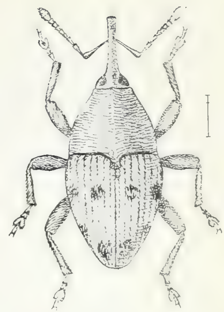

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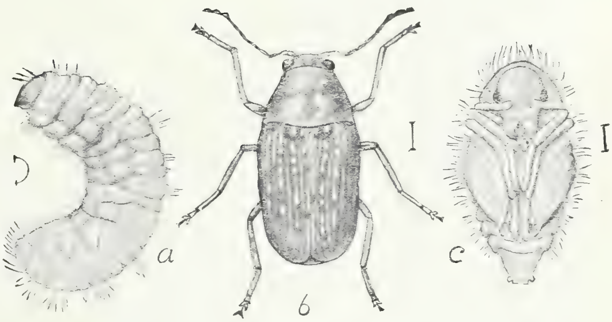

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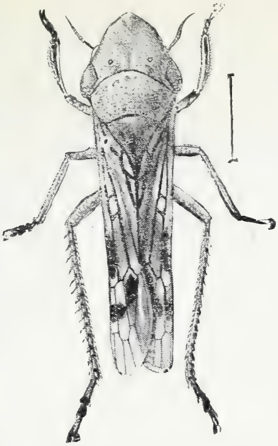
INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Figs. 59, 60, Transverse Baris (*Baris transversa*), much enlarged (original); fig. 61, *Centrinus penicellus*, enlarged (original); fig. 62, coffee-bean weevil (*Aræcerus fasciculatus*): *a*, larva; *b*, beetle; *c*, pupa, enlarged (from Chittenden); figs. 63, 64, *Chalcodermus æneus*, enlarged (from Chittenden).



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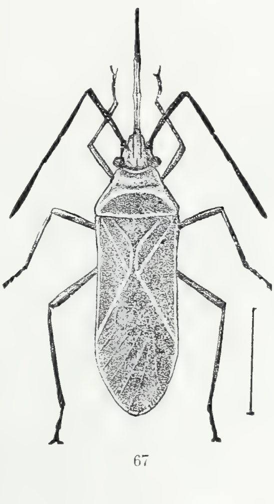

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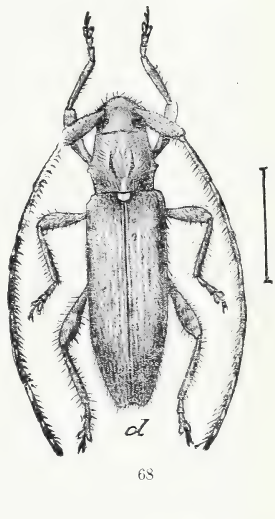

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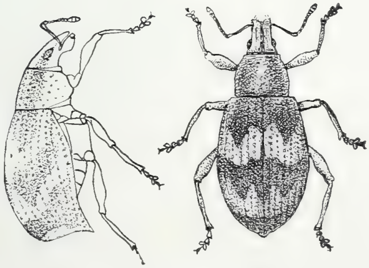

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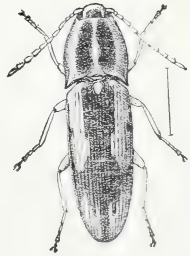

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INSECTS OFTEN MISTAKEN FOR THE BOLL WEEVIL.

Figs. 65, 66, Sharpshooter (*Homalodisca triquetra*), enlarged (from Insect Life); fig. 67, cotton stainer (*Dysdercus suturellus*), enlarged (from Insect Life); fig. 68, cotton stalk borer (*Ataxia crypta*), enlarged (from Howard); fig. 69, imbricated snout beetle (*Epicærus imbricatus*), enlarged (from Chittenden); fig. 70, snapping beetle (*Monocrepidius vespertinus*), enlarged (from Chittenden).

percentage of larvæ and pupæ killed was much larger than in the native. In native cotton about 20 per cent of the larvæ were found to be dead, while in the King 41.2 per cent were dead. In all probability the more rapid flow of sap in the early developing King cotton was largely responsible for the changes which led to the death of the larvæ.

CLIMATIC CONTROL.

INFLUENCE OF CLIMATIC CONDITIONS UPON WEEVIL MULTIPLICATION AND INJURY.

Three principal factors affect the development, spread, and destructiveness of the boll weevil—temperature, precipitation, and food supply. So perfectly has the weevil become adapted to its single food plant that it is a very noticeable fact that the climatic conditions which are most favorable to the growth of the plant are most favorable also for the normal activities and development of the weevil. Affecting one in the same direction as the other, the pest is, therefore, enabled to very closely keep pace with its food supply under all kinds of natural conditions.

The most favorable conditions for the weevil are a high temperature and abundant moisture throughout a long season. These conditions favor the growth of the plant and produce a very large number of squares, which supply abundant opportunity for the rapid multiplication of the weevils. Severe drought checks together the growth of the plant and the development of the weevils. It has not yet been determined whether the death of larvæ in fallen squares exposed directly to the rays of the sun is due principally to the heat produced or to the complete drying of the food supply. It is certain, however, that one or both of these factors produce a large mortality among the larvæ and pupæ so exposed during long-continued hot and dry weather occurring before the plants have become large enough to shade most of the ground. After that the shade produced prevents most of the good work of the sun in destroying weevils.

It is often said by cotton growers that "rain brings the weevils." The principal reasons for this idea are that rains, in squaring time especially, produce conditions greatly favoring the immediate development and subsequent injury of weevils, while at the same time they make more apparent the amount of injury already done. An abundance of rain following a long dry period naturally causes great numbers of squares to fall from purely physiological causes, while at the same time it knocks to the ground such previously infested squares as have become weakened in their connection with the plant and which would fall naturally within a few days. The large number of squares to be found on the ground immediately after a storm would seem to account for the prevalence of the opinion mentioned. A large degree of moisture in fallen squares seems to favor directly the

growth of larvæ within, thus producing quickly a large number of weevils ready to do further injury.

It is still an open question as to how low winter temperatures the weevil can withstand. It is certain that in southern Texas many larvæ and pupæ slowly continue their development during the winter season. Mr. S. G. Borden, of Sharpsburg, Tex., in a letter written January 27, 1896, says: "Hands clearing up cotton stalks report plenty of the larvæ in dry bolls." Mr. Schwarz found weevils hibernating in all stages, except the egg, at Victoria, Tex., during February, 1902. At the same locality in January and February of 1904, the weevils in larval, pupal, and adult stages were taken alive from dry bolls by Mr. J. D. Mitchell, a resident and cotton planter of that place.

After the weevils first made their appearance at San Antonio in the fall of 1895 they were supposed to have been entirely destroyed by frosts during the following winter. The lowest temperature recorded at San Antonio for that winter was 26° F. on December 30, 1895. On January 2, 1896, Professor Townsend made an examination of the condition of the weevil, and, so far as he found, all larvæ in bolls were then dead, while pupæ and adults were all alive. In spite of the mildness of the remainder of the winter the weevils did no damage to the crop of 1896, and were not found in fields in which they were present the year before. In writing of this unexpected condition, on October 19, 1896, Professor Townsend says, "The timely drought of last of May and first of June is what killed the weevils this year." There is therefore some doubt as to whether frosts or drought were responsible for the destruction of the weevils at San Antonio in 1896.

At Victoria, on February 17, 1903, the lowest temperature recorded by the Weather Bureau report was 20° F., but many weevils hibernated successfully. Doubtless much lower temperatures than this were experienced in more northern localities in the weevil belt, but in no place have the weevils been exterminated thereby.

EFFECT OF RAINS UPON DEVELOPMENT OF WEEVILS.

While it is a mistaken idea that rains first bring the weevils, it is true that they favor weevil increase in several ways. Frequent rains increase the growth of the plant and lead to the production of a larger number of squares which may become infested. Driving rains knock off infested squares, and by softening and moistening the food hasten the development of the larvæ within. Squares which are already upon the ground are protected during rainy weather from sunshine and drying. Rain hinders the enemies of the weevil far more than it does the development of the weevils themselves. In several such ways rains contribute directly or indirectly to the more rapid multiplication of weevils and cause the common impression among cotton planters alluded to above.

EFFECT OF WET WINTER WEATHER ON HIBERNATING WEEVILS.

Owing to the writers' absence from Victoria during the winter months, observations could not be made directly or immediately upon this point. It was found, however, that all weevils in hibernation tests which passed the winter successfully had been kept dry. The winter of 1902–3 was unusually wet at Victoria, and the number of hibernated weevils which were to be found on early cotton plants was noticeably less than during previous seasons which had been dry. It seems probable, therefore, that as many weevils perish from frequent wetting as from exposure to the cold.

EFFECTS OF OVERFLOWS IN FIELDS.

Unusually favorable conditions for these observations were obtained at Victoria in the season of 1903. During the latter part of February an overflow of the Guadalupe River covered many of the cotton fields along its course. The fields in which especial study was made were wholly submerged from one to several days. Cotton was planted in some of these fields between March 15 and 17. Owing to cold weather the growth of the plants was delayed and squaring did not begin until between May 10 and 17. Immediately after this date it was found that weevils were present and at work, and fallen squares were first found about May 23. From a study of this field it became apparent that the overflow had caused a considerably less decrease than had been anticipated in the number of hibernating weevils. Possibly the fact that the winter of 1902–3 had been exceptionally rainy may account for the lack of contrast in weevil abundance in overflowed fields and those which did not suffer in this way since, as has already been noted, hibernated weevils were unusually scarce, even on uplands.

Another period of high water occurred during the last of June and the first of July and gave a convenient opportunity to note its effect upon active weevils. Many fields were partially and some wholly submerged. This condition lasted for several days. Examination made after the recession of the water showed that many fallen squares which had certainly been in the water for some time contained uninjured larvæ and pupæ. Naturally eggs and larvæ found in squares upon the plants, even though under water for some time, escaped unharmed. Weevils were working normally upon the plants. No diminution in their numbers could be seen and it was apparent that the overflow caused no check either to the development of the immature stages or to the activity of the adults. These observations emphasize the fact that the weevil can not be drowned out.

LABORATORY OBSERVATIONS UPON TIME WEEVILS WILL FLOAT OR ENDURE SUBMERGENCE.

These tests were divided into two parts, each of which includes both the immature and mature stages. In each part floating and submergence were tested.

Sixty squares, believed from external examination to be infested, were floated in a driving rain for six hours. They were then removed and left for several days, during which time 75 per cent of them produced normal adults. Ten squares which were floated in driving rain for six hours were opened at once, and in every case found to be but slightly wet upon the inside. These contained 6 larvæ and 4 pupæ, and all were in perfect condition.

As squares float normally, submergence tests were considered extreme. Five squares were submerged for six hours, and after that produced 3 normal adults; 1 pupa died, and 1 square was found to have been uninfested. Five more squares were submerged for thirty-one hours. These produced 2 normal adults, and 1 pupa died in the process of molting after removal from the square. Death was probably caused in the last case by drying; 1 square was found to contain a dead pupa, and 1 was not infested. To test the possibility of its living, should the square be penetrated by water, a naked pupa was submerged for six hours, but in spite of this unusual treatment it produced a normal adult.

In the tests made upon the floating power of adults, weevils were isolated and placed in water in tumblers. They were dropped from a considerable distance above the surface, so that they became entirely submerged, and then floated to the surface naturally. The surface tension of the water was found to be sufficient to float weevils which were placed upon it carefully. The generally hairy condition of the surface of the weevil's body prevents its being readily wetted, so that it may struggle for some time in the water without becoming really wet. When dropped in this way weevils float head downward, with the tip of the abdomen above the surface. In the submergence tests weevils were held down by a wire screen, and all bubbles were removed from their bodies by a pipette, thus making the tests as severe as possible.

TABLE XXVI—*Effects of floating and submergence on all stages.*

Conditions of test.	Time in test.	Dead at end of test.	Time before examination.	Normal adults after test.	Remarks.
	Hours.		*Days.*		
Sixty squares floated in rain.	6	--------	4 to 8	45	5 squares contained dead larvæ; 3 pupæ destroyed by ants, and 7 uninfested.
Ten squares floated in rain	6	None.	None.	--------	Squares but slightly wet inside. 6 larvæ and 5 pupæ all alive and normal.
Five squares submerged	6	--------	7 to 8	3	1 pupa dead; 1 square uninfested.
Do	31	1 pupa.	None.	2	1 pupa and 2 larvæ alive after test; squares not wet much inside.
One naked pupa submerged	6	0	--------	1	
Ten adults floated	25	0	--------	6	
Do	112	1	--------	2	6 recovered so as to feed, but 4 died in from 2 to 7 days; 1 lived 36 days and laid 58 eggs.
Five adults submerged	3	0	--------	3	
Do	15	2	--------	3	2 males died soon; females laid 43 eggs in 15 weevil-days.
Ten adults submerged	25	9	--------	0	1 lived through test, but never fed.
Fourteen adults submerged	48	14	--------	0	

In the case of squares floating normally it is evident that they might remain in water for several days without injury to the weevil within. Very slight wetting of the cell takes place even under the extreme conditions of submergence. The effect of a brief flood would not, therefore, be at all injurious. As adults float as readily as do squares, they may also be carried long distances, and, furthermore, they are able to crawl out of the water onto any bushes, weeds, or rubbish which they may touch. Even when floating for several days continuously they are able to live and may be carried directly to new fields. The floating of adults and infested squares explains the appearance of weevils in great numbers along high-water line immediately after a flood, and indicates that probably the most rapid advance the pest will make in the United States will be into the fertile cotton lands of the Red River Valley in Louisiana.

PROBABILITIES AS TO THE INFLUENCE OF CLIMATE ON THE WEEVIL IN COTTON REGIONS NOT NOW INFESTED.

The influence which the lower temperature prevailing over the northern edge of the cotton belt may have upon the development, destructiveness, and spread of the weevil is as yet largely problematical. No considerable amount of accurate data upon the development of the weevil being at present available except that collected at Victoria, Tex., during the seasons of 1902 and 1903, it is impossible to predict with certainty how far or how rapidly the weevil may spread or the rapidity of development which may take place under the different climatic conditions prevailing in regions not at present infested, or whether it may be expected that its destructiveness to cotton will be materially reduced in other sections. These questions are, however, of considerable interest because of the probability that the

weevil will ultimately spread over the entire cotton belt in spite of any measures which may be adopted to retard its progress.

During the past century the attention of many botanists and zoologists has been drawn to the relations existing between geographic areas and the distribution of plants and animals. In this country the limits of the well-defined zones and the laws governing the distribution of plant and animal life through those zones have been most carefully determined by Dr. C. Hart Merriam, Chief of the Division of Biological Survey of the United States Department of Agriculture.[a] A few years before the publication of Doctor Merriam's completed results Dr. L. O. Howard, Chief of the Division of Entomology, first applied the principles underlying geographic distribution to a study of the probable spread of a number of species of very injurious insects, most of which had been imported into this country,[b] and recently he has made a more extensive study of a very practical nature concerning the geographic distribution of the yellow fever mosquito.[c] Many observations have shown that in general the limits of the spread of an imported insect pest may thus be approximately determined. It is, therefore, not out of place to consider at this time some points in regard to the probable status of the boll weevil in the cotton belt outside of Texas.

According to the map published by Doctor Merriam, the entire cotton-growing area of the United States lies within the Lower Austral Zone, the northern limit of which is marked by the isothermal line showing a sum of normal positive temperatures (above 32° F.) amounting to 18,000° F. The weevil has already become established near Sherman, Tex. As nearly as can be told from data at present available, the isothermal line passing through Sherman, if extended eastward, would pass along the Red River Valley, through the extreme southern part of Arkansas, across central Mississippi and Alabama, a little south of Atlanta, Ga., and thence curve northeastward through South and North Carolina. It therefore becomes evident that "temperature" will not prevent the spread of the weevil eastward. Even if it should not go beyond the isothermal line within which it now thrives, its territory would still include most of the great cotton belt of the United States. Furthermore, there is no evidence to show that the weevil has yet reached its most northern limit, and the probabilty remains that it may yet show itself capable of existing anywhere within the Lower Austral Zone where cotton can be grown.

A comparison of the positive temperatures of various localities in the

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[a] Bulletin 10, U. S. Dept. Agr., Division of Biological Survey, Life Zones and Crop Zones of the United States.

[b] Proc. Entom. Soc. Washington, Vol. III, No. 4, pp. 219–226. "Notes on the Geographic Distribution in the United States of Certain Insects Injurious to Cultivated Crops."

[c] Treasury Department—Public Health Reports, Vol. XVIII, No. 46. "Concerning the Geographic Distribution of the Yellow Fever Mosquito."

northeastern part of the cotton belt with that of Victoria, Tex., during the six months from June 1 to November 30, 1902, naturally reveals a considerable range of difference, as does also a comparison of the average temperatures prevailing in those localities during the same period for the preceding eleven years. Wherever it is considered in its effect upon the development of the weevil the temperature given is expressed in degrees of effective temperature—that is, the actual temperature above 43° F. The mean average effective temperature for any month multiplied by the number of days included has been considered as giving the total effective temperature for that month. While this method does not give exactly the correct figures, it will furnish data for a comparison of the various localities, and this study of temperatures will undoubtedly reveal facts which will exert considerable influence upon the status of the weevil in other localities into which it is liable to spread.

The total effective temperature for Victoria, Tex., from June 1 to November 30, 1902, was 6,607° F. For the same period at Dallas, Tex., it was 5,626° F., and at Atlanta, Ga., it was 5,052° F.

The average mean total effective temperatures for the sections of Texas, Louisiana, and Georgia, as given by the Weather Bureau for a series of eleven years, are as follows: Texas, 5,716°; Louisiana, 5,578°; Georgia, 5,234° F.

The effect of this decrease in temperature will doubtless be in some measure counteracted by a certain degree of adaptation thereto on the part of the weevil, but it still seems probable that in the temperature of Georgia a considerable reduction in the number of generations will be found. The emergence from winter quarters will probable be considerably later than the middle of April. The development of progeny will not be as rapid as has been described for Victoria, Tex., in preceding pages. Furthermore, it seems likely that during the warmest periods the life cycle will require from 22 to 28 days. The consequent limited number of generations in a season will be still further curtailed by the earlier period of hibernation, which it seems will begin as early as the latter part of October or the first of November, instead of during December, as was the case during the past two years at Victoria. The date of the killing frosts will, in a general way, fix the end of the active season for the weevil, and this will therefore vary considerably from year to year.

TABLE XXVII.—*Temperature comparisons of various cotton sections.*

Month.	Monthly average normal mean for 11 years, 1892–1902.						
	Victoria, Tex., average (1902 and 1903 only).	Dallas, Tex.	Shreveport, La.	Atlanta, Ga.	Texas section.	Louisiana section.	Georgia section.
	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*	° *F.*
June	75.0	80.5	79.9	78.0	80.6	80.1	78.2
July	80.8	83.3	82.4	80.3	88.9	83.5	80.1
August	80.2	82.8	82.5	79.2	82.8	81.6	79.0
September	77.6	77.4	77.8	70.2	77.3	77.1	74.7
October	71.6	68.1	67.1	62.6	67.9	67.7	64.5
November	63.7	56.7	56.8	57.8	57.3	58.9	58.9
Average for 6 months	74.8	74.8	74.4	71.2	74.6	74.6	72.2

From these considerations of temperature difference and judging the varying influence as ascertained at Victoria, it seems that the weevil may prove less and less destructive as it spreads to the cooler portions of the cotton belt, though this supposition is likely to be nullified by an ability to adapt itself to new conditions.

While it must be admitted that nothing, so far as now known, seems certain to prevent the spread of the weevil to any latitude where cotton is now grown, it does seem probable that its control may be more easily accomplished in the more northern portions of the cotton belt than in the Texas area now infested, and since it has been most positively demonstrated that better than the average crop may here be grown in spite of the depredations of the weevil, there would seem to be no special reason for a panic over the future of the cotton crop. Cotton has been and still will be grown in spite of the weevil. The present promise is that those planters who enter the struggle with determination, and who adopt the advanced methods which have proven successful wherever tried, will realize practically as large a profit from cotton raising in the future as it has been possible to obtain in the past.

DISEASES.

Especially in moist breeding jars, weevils often die from what appears to be a bacterial disease. The body contents liquefy, turning to a dark brown in color, and have a putrid odor. Death follows quickly, though not until after putrefaction has begun. The frequency with which several weevils died in the same jar at about the same time indicates that this disease may be contagious. It has not been found in the fields, however, and may have been due entirely to abnormal laboratory conditions.

It is doubtful whether the following observations upon fungus attacks upon weevils should properly be classed with diseases, but as there is a possibility that the attack may have been of this nature, the observations may be given here.

In July, 1902, a lot of squares sent by mail from Calvert, Tex., to Victoria, was so long delayed upon the road that they were very

moldy when received. Thirteen apparently healthy pupæ were removed from these moldy squares with the intention of rearing the adults. The pupæ were kept moist, and in a short time 5 died, apparently from the attacks of an unknown species of fungus. The remainder were then kept dry, but in spite of this precaution 6 more died, only 2 becoming adult. In another lot of 27 pupæ, 5 died, apparently from attacks of the same fungus.

Specimens of the dead pupæ were sent to the pathologist of the Bureau of Plant Industry of the Department for determination of the fungus. It was pronounced to be a probably new species of *Aspergillus*. As no species of this genus is known to be parasitic, it may be that the pupæ died from some other cause and that the fungus was entirely saprophytic. The external appearance of the fungus so soon after the death of the pupæ, the large mortality prevailing, and the known fact that pupæ develop uninjured in the presence of many species of molds leads to the suspicion that it may have had some part in causing the death of the insects.

In 1894 Prof. C. H. T. Townsend, while engaged in the study of the boll weevil, found in a field at San Juan Allende, Mexico, a specimen of a dead pupa which had been attacked by a species of parasitic fungus (*Cordyceps* sp.). As no other cases of attack by this fungus have been reported, its occurrence is probably very rare.

PARASITES.

BREEDING OF PARASITES.

Owing to the importance attached to parasites in the control of many pests, considerable time has been devoted to the rearing of parasitic enemies of the boll weevil. From the very nature of the habits of the weevil, no perfectly satisfactory method of breeding these parasites could be devised. The apparatus used was exceedingly simple. Squares which were thought to be infested were picked or gathered in the field, and cleared, so far as was possible, of all that might produce parasites not developed from the weevils. Small lots of these squares were placed in paper bags, each fitting tightly over the open mouth of a glass jar. As both parasites and weevils upon emergence naturally make their way to the light, they could easily be seen in the glass jars and at once removed. Even when thus bred something must be known of the habits of each species of insect produced or of its close allies to determine whether it is really a parasite upon a weevil larva, a hyperparasite, or merely a vegetable feeder developed in the decaying square. Many small flies breed in such decaying matter and were caught in the jars, but these must all be acquitted of being parasites upon the weevil. The results are therefore made somewhat uncertain because of the impossibility of isolating the weevil larvæ. A condensed summary of the results in breeding parasites through two seasons' work is presented in Table XXVIII.

Table XXVIII.—*Breeding of parasites.*

Locality.	Collector.	Date.	Squares.	Weevils bred.	Parasites.	
					Bracon mellitor.	Other species.
Squares picked from plants and from ground.						
		1902.				
Calvert, Tex	G. H. Harris	July, August	2,566	277	3	1
Victoria, Tex	W. E. Hinds	do	645	210	1	1
Guadalupe, Tex	W. D. Hunter W. E. Hinds	August	387	108	1	0
		1903.				
Victoria, Tex	W. E. Hinds	June	881	278	10	0
Do	do	July	264	111	3	1
Do	do	August	463	251	0	0
Infested squares dried on the plants.						
Victoria, Tex	W. E. Hinds	July, August	342	120	45	5
Total			5,548	1,355	63	8

From these observations it appears that 24.4 per cent of the 5,548 squares used produced adult weevils, while only 1.3 per cent of the total squares contained parasites. Among the parasites obtained, 90 per cent were of the single species *Bracon mellitor* Say (fig. 4). A single specimen of another undoubtedly primary parasite, *Sigalphus curculionis* Fitch, was reared. A few specimens of *Catolaccus incertus* Ashm. may possibly have come from the weevil larvæ, but were more likely hyperparasites. According to the authority of Dr. William H. Ashmead, of the United States National Museum, to whom the writer is indebted for the specific determinations and also for information about the usual habits of these parasitic insects, the following species, which were bred from squares, must probably be credited to some other host than the boll weevil: *Chalcis coloradensis* Cress. and *Goniozus platynotæ* Ashm. were probably upon lepidopterous larvæ; *Eurytoma* sp. and *Eupelmus*, two spp., usually attack dipterous larvæ in galls and a number of specimens of a species of *Ooencyrtus* may have been parasitic upon the eggs of some lepidopteron or hemipteron, but certainly could not have reached the eggs of the weevil.

Fig. 4.—*Bracon mellitor*, parasite of boll weevil—much enlarged (original).

It is very noticeable that the dried squares which were picked from the plants produced by far the largest part of all the parasites obtained, 342 squares giving 50 parasites. In this lot, therefore, 14 per cent of the total number contained parasites of some kind and 13 per cent were undoubtedly developed from the weevil larvæ. Taking all other squares together, 5,286 yielded only 18 primary parasites, or only 0.3 per cent.

Previous efforts to breed parasites of the weevil yielded as meager results as those which have just been recorded, though they add to the number of species. In 1894 Prof. C. H. T. Townsend bred, at Corpus Christi, Tex., a single specimen of *Urosigalphus robustus* Ashm., which was in all probability a primary parasite, as was also *Bracon dorsata* Say, of which Mr. Schwarz obtained two specimens at Goliad, Tex., in the fall of 1895. A specimen of *Eurytoma tylodermatis* Ashm., also reared by Mr. Townsend, may possibly have had some other host.

Pediculoides ventricosus Newp.—This small mite has been thought by some scientists to be the most promising parasite yet found attacking the weevil. It has been experimented with quite extensively by Prof. A. L. Herrera and his assistants of the Mexican Commission of Parasitology. The mites breed with extreme rapidity, the larvæ of wasps being their usual hosts. Both sexes attain full physical and sexual maturity while yet within the body of the mother. The males are exceedingly tiny, as are also the females, when they first leave the mother mite. As the females become gravid, however, their abdomens swell to an astonishing size as compared with the rest of the body, being distended by the rapid growth of the young mites (fig. 5). When these are born the mother dies, while the offspring mate, and then immediately begin the search for food. The idea of the Mexican investigators was that these tiny parasites would be able to enter the square through microscopic orifices in the outer layers, and that they would attack and destroy the weevil larvæ and pupæ within. Upon his return from a trip to Mexico in the fall of 1902, the senior author brought with him, through the kindness of Pro-

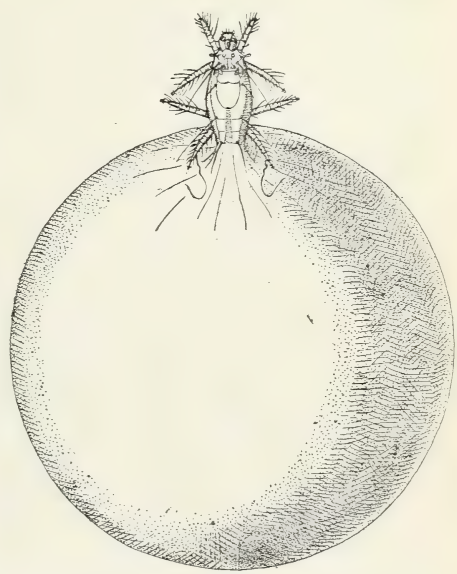

FIG. 5.—Enemy of cotton boll weevil, *Pediculoides ventricosus*—much enlarged (adapted from Brucker).

fessor Herrera, a supply of the parasites, from which others were reared for experimental work in Texas.

In the course of these experiments the possibility of the mites attacking larvæ, pupæ, or immature adults was tested. The observations made failed to show any positive ability on the part of the Pediculoides to penetrate the squares, as in only two cases were mites found in them and attacking the larvæ. In these two cases it seems entirely possible that the mites may have entered through feeding punctures or some other rupture in the floral envelopes.

Upon several occasions during the season of 1903 mites were distributed in badly infested cotton fields. Later examinations were carefully made, but they failed to show that the parasites had gained a hold or even that they had attacked the weevils in any stage.

These mites, if, indeed, they are of the same species as those described by Newport, are widely distributed and attack, to some extent, quite a large number of insects. If they really possessed the ability to get at the weevil larvæ and the predisposition to attack them when they could get to them in preference to other hosts, they should certainly have shown something of these capabilities somewhere within the infested area in Texas during the ten years that the weevil has been found there. As no such ability has yet been shown, we doubt that the Pediculoides will ever prove of any value as a parasite of the weevil in the United States, though it may be more efficient in more southern countries. Furthermore, it is said that even where the mites do become established they are so subject to the attacks of small ants that their efficiency becomes largely destroyed.

Several attempts have been made by agents of this Division to breed parasites of the weevil in localities which must be much nearer its original home than is Texas, but thus far these attempts have proven as fruitless as have those made in Texas. It seems desirable that this work should be continued so as to give a more complete knowledge of all the parasites of the weevil in its native home.

These results show how insignificant is the part which insect parasites play in the problem of controlling the boll weevil in Texas. The thorough protection of all immature stages of the weevil by several layers of vegetable matter and the protection of the adult by its hard, closely fitting, chitinous, external plates renders very small the hope that any parasite will ever become an efficient factor in controlling this dangerous pest.

There is at present, therefore, no promise of any considerable assistance in the control of the weevil by any parasite now known. Because of its peculiar life history the weevil is unusually exempt from the attacks of parasites. Even should one be found which could attack the weevil in some stage, it would probably still fail to be an efficient means of control, because, from the very nature of its parasitic habits, it is bound to be behind the weevil both in the point

of numbers and in the time of its activity. While such parasites might serve to decrease the numbers of the weevil, every larva that becomes parasitized has already done its damage to a square.

In spite of the present unpromising outlook for the discovery of valuable parasites of the weevil, every effort to find such should be made. While earnestly hoping that effective parasites may yet be discovered or developed, it is folly for planters to neglect or delay the adoption of those methods of decreasing weevil injury which have already proven to be both practical and effective.

PREDATORY ENEMIES.

INSECTS.

Insects which prey upon the boll weevil appear to be even fewer in number of species than are those which are parasitic upon it. The principal enemies of this class are ants, and where common these probably destroy more immature weevils than do the parasites. They are frequently to be found in squares on the ground in the act of destroying larvæ or more often pupæ. Occasionally they have been found entering infested bolls which are yet hanging upon the plants and destroying the pupæ, which had become exposed by the premature cracking open of their cells. In some cases they have been known to destroy young adults which had emerged but not become fully hardened. Several species of ants are concerned in this good work. The most active is a small red ant, *Solenopsis debilis* var. *texana* Mayer? (fig. 6). Another species belonging to the genus Myrmica also does considerable good.

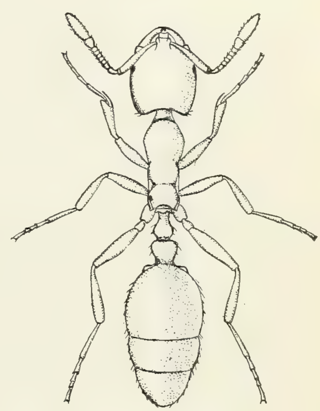

Fig. 6.—*Solenopsis debilis* var. *texana*? ant enemy of boll weevil—much enlarged (original).

Occasionally there may be seen upon cotton plants specimens of a mantis, or "devil horse," as it is more commonly called. One species only, *Stagmomantis limbata* Hahn., has been carefully tested for its ability to destroy weevils. A male of this species was confined in a breeding cage and supplied with a number of adult weevils. Several times it was seen to seize a weevil and attempt to eat it, but being unable to break through the hard chitinous plates which so closely cover the weevil's body, it gave up the attempt and let the weevil go unharmed. Although kept for some time with weevils in its cage, it never fed upon them, but starved to death in their presence. With the female of this species the case is quite different. One was confined in a cage and supplied with an abundance of wee-

vils. It seemed to be more powerful than the male, breaking through the weevil's skeleton with apparent ease. On several occasions it was found to eat 8 or 10 weevils a day. During her period of confinement in the cage she deposited a large batch of eggs, and in the course of about three weeks she destroyed altogether a total of 80 weevils.

Some species of Mantispa also probably devour a few weevils in the field, but the writer has never seen one in the act.

BIRDS.

There can be no doubt that birds are exceedingly valuable assistants to man in reducing the numbers of many insect pests. In order to determine to what extent they feed upon the boll weevils, it is necessary that an extensive study be made of the stomach contents of all birds that may be found in cotton fields. To be at all conclusive such studies must be made in numerous localities and during more than one season. To accomplish this it is deemed advisable to reserve for the present the results of the study of the relation of birds to the weevil problem, that a more complete treatment of the question may be made in some future publication.

METHODS OF COMBATING THE WEEVIL.

The difficulties in the way of controlling the boll weevil lie as much in its habits and manner of work as in the peculiar industrial conditions involved in the production of the staple in the Southern States. The facts that the weevil lives in all stages except the imago within the fruit of the plant, well protected from any poisons that might be applied, and in that stage takes food normally only by inserting its snout within the substance of the plant; that it is remarkably free from parasites or diseases; that it frequently occupies but 14 days for development from egg to adult, and the progeny of a single pair in a season may reach 134,000,000 individuals; that it adapts itself to climatic conditions to the extent that the egg stage alone in November may occupy as much time as all the immature stages together in July or August, are factors that combine to make it one of the most difficult insects to control. It is consequently natural that all the investigations of the Division of Entomology have pointed toward the prime importance of cultural methods of controlling the pest. All other methods must involve some direct financial outlay for material or machinery, and are consequently not in accord with labor conditions involved in cotton production in the United States. Moreover, the cultural methods are in keeping with the general tendency of cotton culture; that is, to procure an early crop, and at the same time have the great advantage of avoiding damage by a large number of other destructive insects, especially the bollworm. Nevertheless, it must not be understood that attention has not been paid

to the investigation of means looking toward the extermination of the pest. As a matter of fact, every suggestion, from the possibility of breeding resistant varieties to the use of electricity in destroying the weevil, has been fully investigated. The results have all been negative.

CULTURAL METHODS.

The cultural method begins with reducing the numbers of the pest in the fall by the destruction of the plants as soon as it becomes apparent that no more cotton is to be produced. The enormous importance of this procedure is shown by the fact already stated (p. 82) that the late issuing weevils are the ones which successfully hibernate. Further strong reasons are given on pages 91 and 92, under the sections "Relations of weevils to top crop" and "Some reasons for the early destruction of stalks." Hosts of weevils may thus be killed, a very small percentage surviving the winter, and in the same operation the ground is better prepared for planting the following season. A large proportion of the weevils thus destroyed would otherwise pass through the winter successfully and increase the damage to the planted cotton the following season. Wherever the cotton is allowed to stand in the fields in the hope that a top crop may be produced opportunities are furnished for the development of a very large number of weevils. As explained before in this bulletin, the possibility of a top crop has always been exceedingly remote. Wherever the weevil exists it is not a possibility at all. The method of fall destruction only involves applying labor that is necessary in any case in preparing the land for planting a few months earlier than is the normal practice among cotton planters. It has been the custom to leave the land uncleared until shortly before planting time in the spring. Now, however, this clearing process is necessary as the last step in the production of the preceding crop. This method, as a matter of fact, is the only practicable strictly remedial method that has been devised.

Simple uprooting of the plants by means of plows, and burning them as soon as sufficiently dry, is very effective; but undoubtedly the most effective way would be to leave a row out of 20 after the general uprooting has taken place, to serve as a trap. When the weevils have assembled upon these plants they might be killed easily with crude petroleum, as the destruction of the plants at that time would be immaterial. Nevertheless the heaps of drying stalks also act as a trap, and consequently, especially in view of the success that attends the method, the average planter will believe the destruction of all the plants in the field a better plan than any modification of it.

The remaining portion of the cultural method consists in furthering the advantage gained by fall destruction by bending every effort toward obtaining a crop that will mature before the weevils have had an opportunity to do considerable damage. The most important factors in obtaining an early crop are early planting, selection of a

rapidly growing variety, fertilization, and thorough cultivation. The success of the planter will be in direct proportion to the extent to which he is able to combine these essentials. Early planting of early varieties will be found to be of comparatively little avail unless followed by thorough cultivation, and in case of unavoidably delayed planting the best hope of the planter will be in persistent cultivation.

As the details of the cultural method have been dealt with fully in the Farmers' Bulletins of this Department, and as the basis for them in the habits of the weevil was fully explained in the preceding pages, it is unnecessary in this connection to more than summarize them:

(1) Fall destruction.

(2) Early planting of rapidly maturing varieties.

(3) Wide spacing, which, besides favoring rapid maturity of the plant, also acts as a remedial measure by allowing the sun to reach the ground and causing the drying up of the squares in which the larvæ occur.

(4) Thorough cultivation.

(5) Fertilization with commercial preparations containing high percentage of phosphoric acid.

In addition to this general system that is applicable to all cotton plantations, favorable labor conditions sometimes make it feasible to pick the infested squares by hand. Nothing could be more out of place than to suggest hand picking upon large plantations. Even with convict labor it has been found entirely impracticable. But, nevertheless, where a planter has only a few acres of cotton and there is an abundance of cheap labor, such as that of children, the method has been found very effective.

FUTILE MEANS.

The very serious nature of the boll weevil problem is constantly illustrated by the manner in which various useless devices and nostrums are brought to public attention. At one time it was widely spread about that mineral paint would act as a specific against the weevil. An equally fallacious theory that also received considerable popular attention was to the effect that cotton-seed meal exerted a powerful attraction for the pest.

Probably the most important useless recommendation has been that of spraying. It was supposed for some time by certain parties that it might be possible to poison weevils economically by attracting them to some sweetened preparation. The experiments detailed on pages 52 to 56 of this bulletin regarding the attraction of various sweetened substances demonstrate the fallacy of the theory. Even if these substances exerted as much attraction as was supposed, there would be insurmountable difficulties in the application of the method in the field. Spraying of a field crop has never been a success and, unless entirely new methods are eventually perfected, never will be of any practical importance. It is true that it is possible to destroy a cer-

tain number of weevils in regions where seppa cotton occurs by heavily spraying the earliest plants, but this method is of immeasurably less importance than the simple practice of cultural methods.

Many attempts have been made to perfect a machine that will assist in the warfare against the weevil. They have been designed to poison the insects, to jar them and infested squares from the plant and to collect them, to pick the fallen squares from the ground, to kill by fumigation, and to burn all infested material on the ground. The Division of Entomology has carefully investigated the merits of representatives of all of these classes, beginning in 1895 with a square-collecting machine that had attracted considerable local attention in Bee County. Up to the present time none of these devices have been found to be practicable or to offer any definite hope of being eventually successful. At one time there was some hope that a machine designed to pick the squares from the ground by suction might be perfected. The experiments, however, have indicated probably insurmountable difficulties; and an implement concern, after having experimented with the matter fully and after having expended over $5,000, has come to the conclusion that mechanical difficulties will always prevent the perfection of such a machine. If it were not possible to raise cotton profitably without the use of a machine, the situation would be changed materially; but since it is possible to produce the staple without the use of any other means than those which enter into cotton culture everywhere, there seems no hope for these machines.

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